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**Multipurpose Arcade Combat Simulator
(MACS)
Year Three Report**

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Litton Systems, Inc.**

for

**ARI Field Unit at Fort Benning, Georgia
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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This research note discusses research accomplished during the period from October 1986 to September 1987. During this period, research focused on three areas: developing software for the M136 Anti-armor Weapon, developing a ten-level BRM cartridge, and developing an eight-level ARM cartridge. Descriptions of all software development are given in the report, and appendixes are provided documenting general software architecture of MACS with detailed flow charts, and detailed outlines of the BRM and ARM cartridges.					
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MULTIPURPOSE ARCADE COMBAT SIMULATOR (MACS): YEAR THREE REPORT

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INTRODUCTION

This report details research conducted on the Multipurpose Arcade Combat Simulator (MACS) system during the third year of a three-year system development contract. ~~Earlier work is reported in Hunt, Broom, Greene, Crawford, Martere and Parish (1987a).~~ The MACS system is a low-cost, computer-based, part-task weapons trainer that was initially developed to facilitate the teaching of rifle marksmanship, but has the potential to train soldiers on other weapons. It comprises a weapon (e.g., an M16 rifle) with a light pen attached to the barrel and a Commodore 64 computer. Targets are displayed on the computer screen at specified ranges; the user may zero the weapon and then practice marksmanship. Diagnostic feedback is provided. The system has been validated as a teaching device, (Evans, 1988).

Research in the third year of the contract has focused on software development in four areas: (1) a 10-level Basic Rifle Marksmanship (BRM) cartridge, (2) an 8-level Advanced Rifle Marksmanship (ARM) cartridge, (3) preliminary development of a cartridge for unit rifle marksmanship training, and (4) development of a program for the M136 anti-armor weapon (AT-4). In addition, minor software modifications were made to the system's demonstration program. These areas are detailed in separate sections in this report. Four appendices are included: Appendix A provides flow charts for the general architecture of all MACS programs other than the BRM and ARM multi-level programs; Appendix B provides a level-by-level outline of the BRM 10-level program and technical documentation of the program; and Appendix C provides a level-by-level outline for the ARM 8-level program. Appendix D describes the work which has been completed on the unit cartridge.

SOFTWARE DEVELOPMENT

Demonstration Program

The modifications made to the demonstration program concerned the presentation of the moving targets, the replay procedure, and the numerical summary of the diagnostics measures. Prior to making these modifications the MACS demonstration program worked as follows. The firer zeroed the weapon by firing three rounds in a supported position at a scaled 250 m E-type silhouette (E-type silhouettes represent a man kneeling, whereas F-type represent a man lying prone). After each round the target disappeared from the monitor and was replaced by a new target. After firing three rounds to zero, the three-round shot group was displayed on a single enlarged 250 m target to provide the firer with feedback on his performance. The main program was then initiated. This consisted of five target exposures, two with stationary and three with moving targets. Exposure time varied from 2 seconds for the nearest moving target, to 6 seconds for the furthest stationary target. The targets were presented in the following sequence: (1) a 300 m stationary E-type target, (2) a 185 m E-type target moving from right to left, (3) a 125 m E-type target moving from left to right, (4) a stationary 100 m F-type target, and (5) a 75 m E-type target moving from right to left. A full replay of each target exposure was given after each shot, which provided the firer with visual feedback about his performance. This replay covered the period from the start of the target sequence to the moment the shot was fired.

For moving targets, the firer received feedback on lead distance, shot location, trigger squeeze, follow through, and either a track or a trap score depending on the firer's engagement technique. A track score is a measure of the steadiness with which the target was led (tracked), and a trap score is a measure of the steadiness with which an anticipatory point of aim was held. This feedback was followed by a new screen showing a replay. The replay showed the perfect lead for the target using a black image of a front sight post, the actual lead using a white image of a front sight post, and the location of the strike of shot using imaged cross hairs.

For stationary targets, the firer received feedback on four diagnostic measures: steady position, trigger squeeze, follow through, and shot location. Again, the replay showed the perfect sight picture with a black front sight post, the actual sight picture using a white overlay of the firer's front sight post, and the location of the strike of shot. For both stationary and moving targets, the diagnostic measures were each expressed numerically on a scale of 0-100, with a high score indicating better performance.

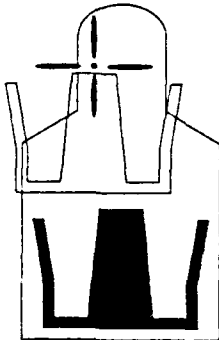
For the most part, the demonstration program remains as is described above. The modifications made were as follows. First, for moving targets, the direction of movement (left to right or right to left) is no longer pre-set, but has been randomized so that a repeat user cannot improve his score by foreknowledge of direction of target movement. Second, the presentation of feedback was changed. The diagnostic information and the replay are now combined on a single screen (see Figure 1) and the replay is continuously repeated. This allows the user time to study the mistakes made and to relate them to the diagnostic information. In addition, diagnostic information is now given using verbal labels rather than numerical scores. This is because verbal labels provide a more readily comprehensible evaluation of a firer's ability than did the numeric scores. Finally, an additional feature was added; the program now maintains a record of the scores obtained by the top five firers along with the each firer's initials. This simulates commercial arcade games and was done to stimulate interest. All other procedures for the demonstration program remain unchanged.

Basic Rifle Marksmanship (BRM) Ten-Level Cartridge

The BRM program uses stationary targets only, and comprises a marksmanship skill test followed by a hierarchically structured 10-level main program. It is designed to assess the firer's skill level and then step him through a progression of ten levels of training. Specific performance standards are set for each level and these standards are incorporated into the program (an outline of the program and the performance standards for each level are provided in Appendix B). After the firer has completed a level, the computer assesses the firer's ability and may then advance him to the next level, keep him at the same level, or regress him one level. In order to provide system flexibility, a hidden menu allows instructors to choose specific levels before entering the program. Regardless of the sequence of operation decided upon, the program automatically begins with a preliminary six-round marksmanship skill test.

The preliminary skill test requires the firer to fire six rounds at a scaled 250 m E-type target, three rounds in a supported firing position and three in an unsupported firing position. The three rounds fired from the supported position are used to electronically zero the weapon (Hunt et al., 1987a). A summary evaluation using the four diagnostic measures (steady position, trigger squeeze, follow through, and shot location) is given after each set of three rounds have been fired. If, in both firing positions, the firer receives an "excellent" score for shot location, plus an "excellent" score for either steady position or trigger squeeze, plus an "average" or better score for follow through, then he immediately progresses to an extended skill test. If the firer does not reach this standard then he begins at either Level 1 or Level 2 of the main training program, depending on the quality of performance recorded in the preliminary test. For example, if the firer scores "excellent" on all diagnostic scores in the supported firing position and less well in the unsupported firing position then the program will branch to Level 2: "Introduction to the Unsupported Position".

LEAD	EXCELLENT
TRACK SCR	AVERAGE
TRIGGER SQ	POOR
FOLLOW THR	GOOD
LOCATION	BELOW AVG



<Pull trigger to continue>

Figure 1. Replay screen for new version of demonstration program.

The extended skill test is used to determine the appropriate starting level for those who have met the standards set in the preliminary test. The extended test comprises six target exposures, divided into two sets of three targets. In each set, the three targets are at different ranges (100, 250, and 300 m). Firers are allowed one shot at each target. The first set of three shots is fired from the supported firing position; if the firer fails to meet the standard on this set, then he is advanced immediately to Level 3. If he meets the standard then he fires the second set. The second set of three shots is fired from the unsupported firing position. Those who do not meet standard on the second set go to Level 4, and those that do are advanced to Level 5.

To summarize, the preliminary and extended skill tests screen firers to determine their marksmanship ability, and hence, the level at which each should enter the program. A summary of each level of the main program is provided below.

Level 1: Introduction to the Supported Position. This level requires the firer to engage a total of 18 stationary targets at six different ranges between 50 and 300 m. Two types of target are used, F-type at 50 and 100 m and E-Type at all other ranges (this is true for all 10 levels). Three separate targets are presented at each range, and the range is increased by 50 m for each subsequent set of three targets. Firing is from the supported firing position, and the task is self-paced. The firer has to obtain hits on two of the three targets at each range to progress to the next range. If this standard is not met, three more targets are presented at the same range. When this occurs, the screen border changes color (from black to red) to alert the instructor that the firer may be experiencing difficulty. A status display in the top left corner of the screen indicates how many firing repetitions have been performed at that range. After each shot, a replay is shown and the diagnostic evaluations of steady position, trigger squeeze, follow through, and shot location are displayed. After three targets have been fired at, a summary screen indicating the three round shot group is provided before the firer is taken to the next target range. When a firer has fired at all six ranges, a summary screen is displayed with average diagnostics scores for each measure.

Level 2: Introduction to the Unsupported Position. Level 2 is identical to Level 1 except all firing is performed in the unsupported position.

Level 3: Timed Targets in the Supported Position. This level requires the firer to engage 24 individual targets at six ranges between 50 and 300 m. Four targets are presented at each range, but the order in which they are presented is randomized so that a 300 m target may be followed by a 100 m target. Firing is from the supported position and the time available to fire at each target is limited. The time constraints set are 33% above those used by the Army for record fire; for example, record fire allows 6 seconds for targets at 200 m and therefore at this level, the program allows 8 seconds. Performance standards are three hits out of four target exposures at each range. If at the end of the 24 target sequence, this standard has not been met at one or more of the six ranges, additional practice is given. Additional practice is as follows; for each range at which the standard was not met, a set of four new targets is presented. Sets of four targets continue to be presented until the firer has had sufficient practice to meet the standard at all ranges. During practice, the screen border color and status display also change in the manner described for Level 1. Immediate diagnostic feedback is provided for both the initial 24 targets and for subsequent practice, but only

when bad shots occur. Bad shots are defined as those in which a poor score is obtained for any diagnostic measure, or a below average score is obtained for shot location. When the firer has met the standard at all target ranges, a summary feedback screen is displayed, showing shot locations at each range on a single target followed by a summary screen indicating average diagnostic scores covering all firing at this level. At this point, using a built-in algorithm, the program makes an assessment of the firer's overall performance, and may move him forward to Level 4, make him repeat Level 3, or may regress him to Level 2. If a firer has to repeat the level, he will receive targets in a different order, so that he is not helped by foreknowledge of the order of presentation.

Level 4: Timed Targets in the Unsupported Position. Level 4 is identical to Level 3 in all respects, except that firing is performed in the unsupported position, and the performance standards for the 250 and 300 m targets are reduced from three out of four hits to two out of four hits.

Level 5: Practice Record Fire I. This level models the actual record fire scenario in terms of the time allowed for target engagements, and the number of targets. Some screens contain a single target and others have double targets so that a total of 40 targets are presented over 29 screens. The first 20 targets (16 screens) are engaged from a supported firing position, and the second 20 targets (13 screens) are engaged from an unsupported firing position. Target exposure times for single targets vary from 3 s for 50 m targets to 8 s for 300 m targets, and from 6 to 12 s for screens with double targets. The location of bullet strike is depicted by cross hairs for both target hits and misses. At the completion of the supported fire section, summary feedback is provided for performance at each of the six ranges. For each range, the shot group is displayed on a single target, followed by a summary table of hits, misses, and no fires. The same feedback is provided after completion of the unsupported fire section. The performance standard for each section is 15 target hits out of the 20 targets. If a firer fails to attain this standard in the supported firing section then he must repeat the section until the standard is met; only then does the program move on to the unsupported firing section. Similarly, a firer must refire in the unsupported position until the standard is met. When the standard has not been met the screen border color and status display change in the manner described for Level 1. When both sections are completed, an overall summary table is displayed showing the number of target hits, target misses, and no-fires by target range. Then, using a built-in algorithm, the program assesses whether the firer should advance to Level 6, repeat Level 5 or regress to Level 4. Because the order in which screens are presented is randomized for both supported fire and for unsupported fire, a firer who repeats at this level will not get target screens in the same order.

Level 6: Practice Record Fire II. Level 6 differs from Level 5 in two respects only, (1) the order of the target screens is different, and (2) bullet strike is shown only for target misses (targets that are hit fall, i.e., they disappear from the screen). All other feedback is identical to that described for Level 5.

Level 7: Record Fire. Level 7 is the same as Level 6 except that the target screens are in a different order, and bullet strike is no longer shown. Targets disappear when hit, and remain visible when missed. Other feedback and the performance standards are as described for Level 5.

Level 8: Rapid Record Fire. Level 8 differs from preceding levels in that the firer is allowed less time to engage targets. Target exposure times are reduced to approximately two thirds of those allowed for record fire (as in Levels 5-7). For example, a target exposed for three seconds during Record Fire would be exposed for approximately two seconds in this scenario. Bullet strike is only shown when the firer misses the target. The summary feedback and performance standards are identical to those described for Level 5.

Level 9: Rapid Record Fire II. This level is the same as Level 8 except the target sequence is different and bullet strike is not shown (targets disappear when hit). Summary feedback and performance standards are identical to those described for Level 5.

Level 10: Combat Fire. Level 10 is an attack/retreat scenario containing a total of 80 targets, that are presented singly or as multiple targets on a single screen (max = 5 targets per screen). The first 40 targets are fired at from the supported position, and if the standard is not met (28/40 hits), the firer is required to repeat this section. The second 40 targets are fired at from the unsupported position, and the standard is 23/40 hits. (A screen by screen description of this scenario is provided in Appendix B). Feedback is provided for bullet strike (depicted by cross hairs) for both target hits and misses, and summary tables of performance are provided at the conclusion of the level.

Advanced Rifle Marksmanship (ARM) Eight-Level Cartridge

The ARM cartridge deals primarily with moving targets. The program consists of a zero routine, an optional demonstration routine, and an 8-level hierarchically structured main program. Levels 1-4 of the main program introduce moving target engagement. The only distinction between these levels is that the targets are at increasing ranges (target ranges for levels 1 through 4 are 60 m, 75 m, 125 m, and 185 m). The speed of the targets, the feedback provided to the firer, and the performance standards are identical. Levels 5 through 8 provide advanced practice using both stationary and moving targets. To zero, the firer fires 3 rounds at a scaled 250 m E-type silhouette from a supported firing position. These three rounds enable the system to electronically zero the weapon (see Hunt et al., 1987a). Once zeroing is complete, the instructor may skip the demonstration routine and move directly to Level 1 of the program. If the demonstration routine is chosen, the firer is presented with 26 separate instructional screens to teach concepts related to leading a moving target. The first gives a demonstration of what happens when no lead is used, the next 12 demonstrate how to apply a perfect lead to a moving target at all four ranges and for three speeds of target movement. This is followed by a series of screens that demonstrate the single lead rule for engaging moving targets, including one example of a situation where the single lead rule should not be applied. Finally, the techniques of tracking and trapping a moving target are taught (see Hunt et al., 1987b for precise details of these techniques). At the conclusion of the demonstration routine, the program takes the firer to Level 1 of the main program.

Level 1: Introduction to Moving Target Engagement. This level presents the firer with moving E-type targets at 60 m. To facilitate the tracking of targets, all firing is from the unsupported position. A total of 18 single targets are presented, divided into six sets of three. The first two sets of

targets move at the scaled equivalent of 2 mph, three moving left to right, and three moving right to left. The next two sets move at 4 mph, and the final two sets at eight mph. Progress from set to set is automatic, however the instructor can over-ride this and advance the firer to the next higher target speed manually by pressing the "CTRL" key. The time allowed per shot is the time the target is on the screen or 5 seconds, whichever is the shorter. After each shot, the firer is presented with a replay and diagnostic feedback on lead, track/trap, trigger squeeze, follow through, and shot location scores. As in the BRM cartridge, the diagnostic scores range from "Poor" to "Excellent". The replay shows the perfect lead with a black front sight post for engaging the target and an overlay of the firer's front sight post in white. After a set of three targets has been engaged, feedback is provided showing the shot group on a single target. Performance standards are two target hits out of three target exposures. If the standards are not met, three more targets are presented at the same speed, and moving in the same direction. Once the standards are met for all sets of three targets the firer progresses to Level 2. Levels 2, 3, and 4 of this program are identical to Level 1 except that the target ranges are increased to 75, 125, and 185 m respectively.

Level 5: Practice Fire I. This level comprises 36 randomly presented single target exposures. Both stationary and moving targets are used; all targets are E-type except the 50 and 100 m stationary targets which are F-type. Twelve stationary targets are presented, two at each of the ranges 50, 100, 150, 200, 250, and 300 m. The remaining 24 are moving targets, and are evenly distributed across the four ranges (60, 75, 125, and 185 m), the three speeds of movement (2, 4, and 8 mph) and the two directions of movement (to the left or to the right). Stationary target exposure time is approximately two thirds that of exposure times for Levels 5-7 on the BRM cartridge (i.e., between 2 and 6 seconds). Moving target exposure times depend on target range and speed and vary between 1-5 seconds. Diagnostic feedback is provided for bad shots only. A bad shot is defined as a shot in which the firer scores "Poor" for any diagnostic measure or "Poor"/"Below Average" for shot location. The replay routine is the same as that described for Level 1. At the completion of the scenario, a summary table showing target hits, target misses, and no fires is given. Performance standards at this level are: two hits out of three target exposures for moving targets, two hits out of two target exposures for stationary targets between 50 and 250 m, and one hit out of two target exposures for stationary targets at 300 m. Firers who fail to qualify are required to refire the level.

Level 6: Practice Fire II. Level 6 is a 30 target scenario comprised of 10 stationary and 20 moving targets. Single and multiple target exposures are presented from 50-300 m. The firer is allowed 40 rounds to engage the 30 targets (a hidden option allows the instructor to specify any number of rounds between 30 and 40). Only shot location feedback is provided, with cross hairs depicting bullet strike. A summary table is presented at the completion of the scenario indicating the number of target hits, misses, and no fires. The performance standards require the firer to hit 15 out of 20 moving targets and 8 out of 10 stationary targets. Failure to meet these standards necessitates a refire of the level.

Level 7: Combat Fire I (Attack/retreat). This is a 30 target attack/retreat scenario comprising 10 stationary and 20 moving targets. Single and multiple target exposures are presented at ranges between 50 and 300 m. Multiple target presentations consist of two or more targets presented

simultaneously. On screens showing multiple targets, the targets can be all stationary, all moving, or a combination of stationary and moving. In addition, the moving targets can travel in different directions at different speeds (see Appendix C for a detailed outline of this scenario). Shot location feedback is provided with cross hairs depicting bullet strike for target hits and misses. At the conclusion of the scenario, a summary screen is provided indicating the number of target hits, target misses, and no fires. Performance standards are identical to those described for Level 6.

Level 8: Combat Fire II (Counterattack/retreat). Level 8 is a 30 target counterattack/retreat scenario comprised of 10 stationary and 20 moving targets. Single and multiple target exposures are presented from 50-300 m. Target presentations for multiple targets are the same as in Level 7 except moving targets are capable of stopping and changing direction (see Appendix C for a detailed outline of this scenario). Feedback and performance standards are as for Level 7.

Unit cartridge

This program is designed for individual training, and has therefore been structured like a coin-operated arcade game with a point scoring system. This was done to stimulate interest and competitiveness. Points are earned for hitting targets. Each target is assigned a point value, the closest targets having the smallest values. Values are further weighted by factors such as achieving a dead-center hit, or successfully engaging targets that are exposed for less time than record fire allows.

The unit program has three levels, adapted from Levels 6-8 of the ARM cartridge. The firer begins by shooting one round into the center of a 250 m E-type silhouette target to obtain an initial zero. The next two targets, also 250 m E-type silhouette targets, are used by the system to further zero the light pen to the sights; but they also provide a scoring opportunity for the user. After zeroing, the firer enters the program at Level 1.

At each level, the firer is presented with thirty targets which he must engage with forty rounds of ammunition. Multiple shots can be fired at any target. Failure to hit a target within the time limit is penalized by the loss of a further five rounds; failure to engage a target is also penalized by the loss of 5 rounds. The game continues until the level is finished, at which time the next level is entered. If the firer exhausts his supply of ammunition while targets still remain, he loses and must start at Level 1 again.

Further work is expected on the unit cartridge, including the addition of wind effects. A list of current and in-built, but as yet unexploited, features may be found in Appendix D.

M136 Anti-armor weapon (AT-4)

The AT-4 program for MACS was designed to provide soldiers with realistic part-task training in the firing procedures for the AT-4 weapon system. The program is hierarchically structured into three levels of difficulty. Level 1 uses stationary targets, Level 2 shows slow moving targets (6-7 mph), Level 3 shows fast moving targets (12-14 mph).

Upon entry into the program, the firer is required to fire three zeroing rounds at a scaled 250 m BMD target. These three rounds are used to calculate an average offset value for the X and Y light pen readings gathered during each shot. The offset is used throughout the program to calculate the round impact coordinates after each shot is fired.

After zeroing is complete, and before the start of Level 1, a screen showing four BMD targets set against a background scene is displayed. One target is shown at each of the four ranges that are used (125, 150, 250, 300 m), the targets being appropriately scaled to size (see Figure 2). This familiarizes the firer with the size of the target images as they correspond to the ranges. The firer requires this knowledge to perform the task because the range that he estimates and sets on the weapon sights will affect the trajectory of the round, and hence whether he scores a hit or a miss.

At this point, the instructor can access a hidden menu (by pressing the "M" key) and select certain options: (1) he can select whether a demonstration feature should precede each level, (2) he can determine at which level(s) the soldier will be trained, (3) he can select the firing position in which the soldier will be trained. If the demonstration feature is selected, then prior to the start of each level, two examples of correct sight placement are given. The examples use targets at 250 m, show where the sight should be placed on stationary targets, and the appropriate lead required for moving targets.

The system provides a choice of five firing positions (prone, kneeling, sitting, standing, and foxhole unsupported). The information on the firing position is important because the system recognizes, for example, that firing from an unsupported standing firing position is more difficult than firing from a sitting position, and adjusts scoring to take this into account.

Each level of the program comprises eight single target exposures, two at each of the four target ranges. Of the two at each range, one moves left to right (Level 2 and 3) or faces right (Level 1 - stationary target), and the other moves or faces to the left. Prior to engagement, the firer estimates the range of the target. Ranges are displayed numerically at the bottom of the screen and are automatically illuminated in turn. When the firer's estimate is illuminated he depresses the safety switch on the weapon to record his estimate. He then has 4 seconds to adjust the rear sight (the rear sight of the AT-4 is adjustable from 100-500 m in 50 m increments). If the target range is not estimated and indicated within 16 seconds, a "no fire" is recorded. If the target range is estimated incorrectly, then the trajectory of the round is affected. During the four second sight adjustment period, text is on the screen and the weapon cannot be fired. The text then disappears and the engagement period starts. The firer must engage the target within 7 seconds; failure to do so is recorded as a "no fire".

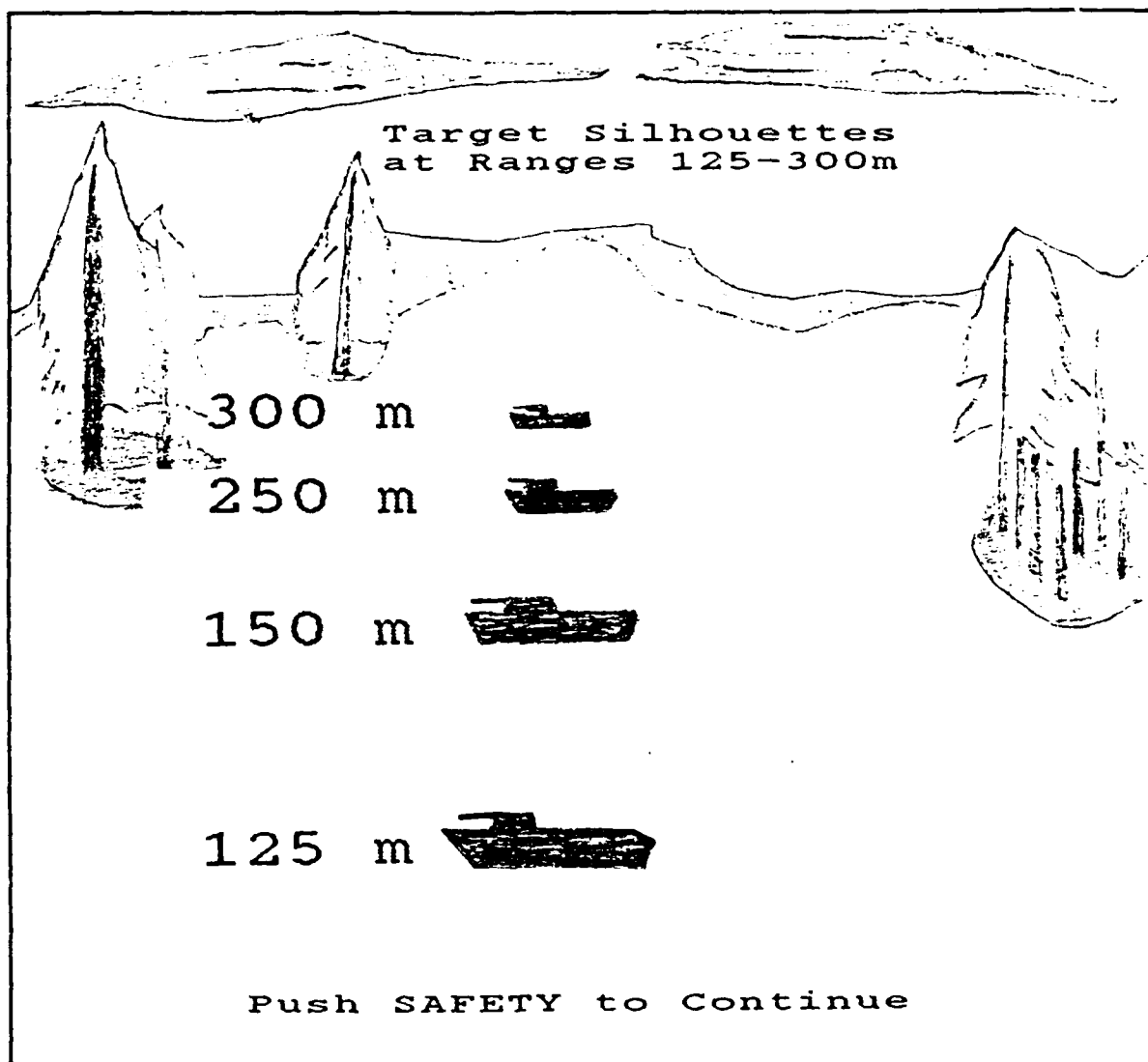


Figure 2. Background scene with scaled representations of BMD targets.

The firing procedure for this program replicates the procedure on the actual weapon. Once the firer has estimated the target range and adjusted the rear sight, he has to depress the safety switch before pressing the trigger. When the safety is fully depressed (safety is off), the color of the border around the screen changes from black to red; this tells the firer that the weapon is armed and ready to be fired. If the safety is not fully depressed when the trigger is pressed, or if the safety and trigger are activated out of sequence, then the border around the screen changes from black to blue and the weapon will not fire. This indicates to both the instructor and the firer that the weapon is not being operated correctly.

After each shot, a replay shows the firer's sight movements and placement in white, superimposed over the correct sight placement (in black). Round impact location is indicated by cross-hairs. In addition, summary scores (in the form of descriptive labels) are given in a table at the top of the screen, for steady position, trigger squeeze, follow through, and shot location. After the completion of each level, a summary screen is provided indicating the number of target hits, target misses, and no fires. Similarly, at the completion of a training session (which may include all three levels), an overall summary is provided.

Level 1 presents stationary targets in sequence from 125 to 300 meters. Level 2 uses the same targets, in a different order, moving at the equivalent of 6 to 7 mph. Level 3 also uses the same targets, but in a third order, moving at between 12 and 14 mph. Levels 2 and 3 incorporate the use of lead rules for the M136. The correct lead for the speed of the target is taught in the demonstration feature and in the replays. At present no performance standards have been developed for the AT-4 program, advancement from level to level is either automatic or at the discretion of the instructor.

SUMMARY

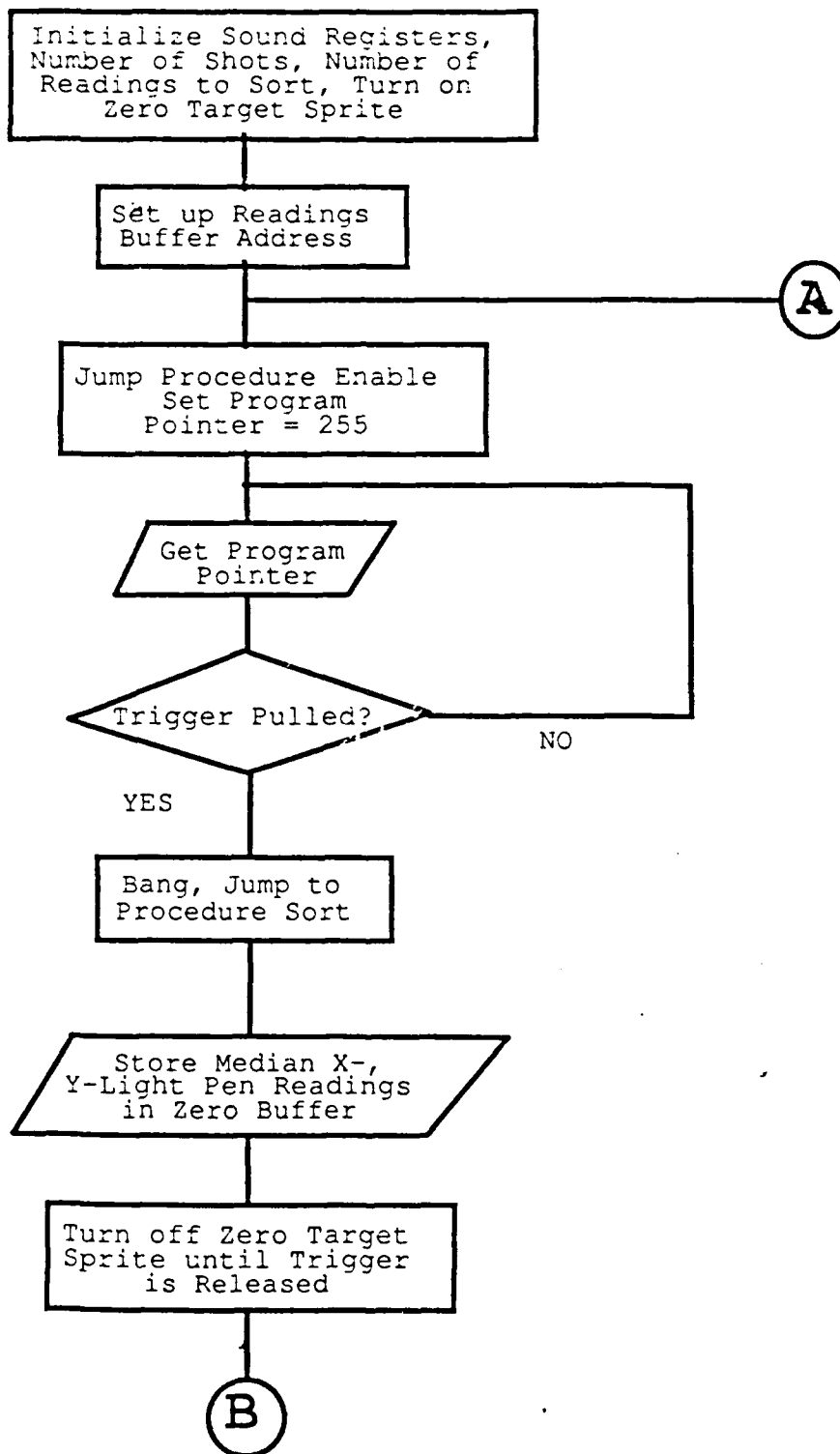
The work completed comprised minor modifications of the demonstration program, the development of a new program for the M136 anti-armor weapon, and the development of two major programs for the M16 rifle (the BRM and ARM cartridges). The time required to develop the software has limited the time available for field validation, however, a concept evaluation test has been conducted by the U. S. Army Infantry Board (USAIB) using the BRM 10-level cartridge. Future development of this software will require a full field evaluation to determine the efficacy of the instructional design in terms of the presentation of levels, the use of feedback, and the utility of the performance standards associated with each course of fire.

REFERENCES

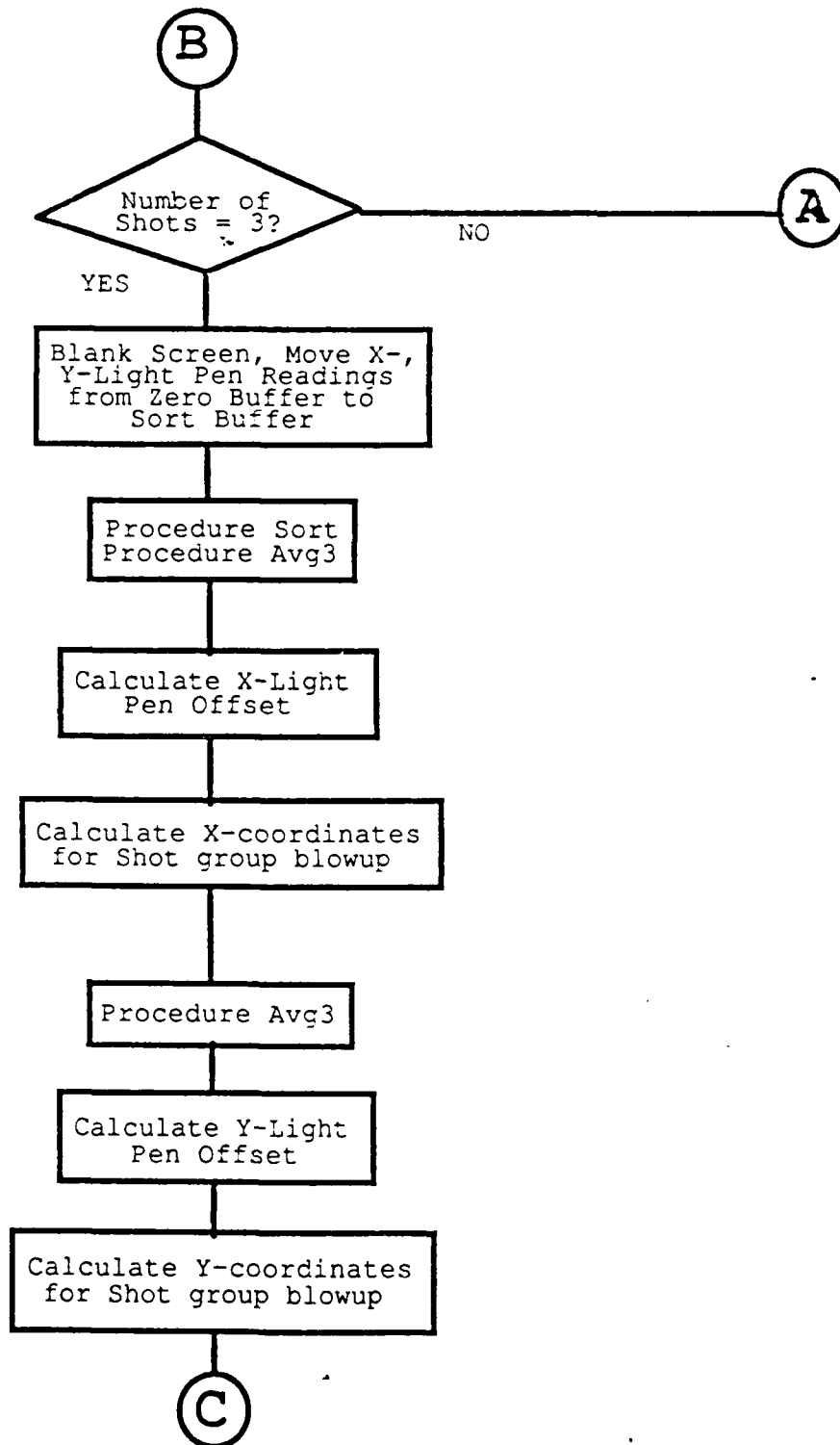
- Evans, K. L. (1988). Development and evaluation of the multipurpose arcade combat simulator (MACS): a research summary (ARI Research Report) Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (In processing)
- Hunt, J. P., Broom, J. M., Greene, W. H., Crawford, J. W., Martere, R. F., and Parish, J. R. (1987). Multipurpose arcade combat simulator (MACS): Year two report (ARI Research Note No. 87-34). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A184 179
- Hunt, J. P., Parish, J. R., Martere, R. F., Osborne, A. D., and Evans, K. L. (1987). The development and evaluation of moving target engagement training programs with the M16A1 rifle (ARI Technical Report No. 758). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A190 847

APPENDIX A: FLOW CHARTS OF MACS FOR THE GENERAL ARCHITECTURE OF ALL
MACS PROGRAMS OTHER THAN THE BRM AND ARM MULTI-LEVEL PROGRAMS

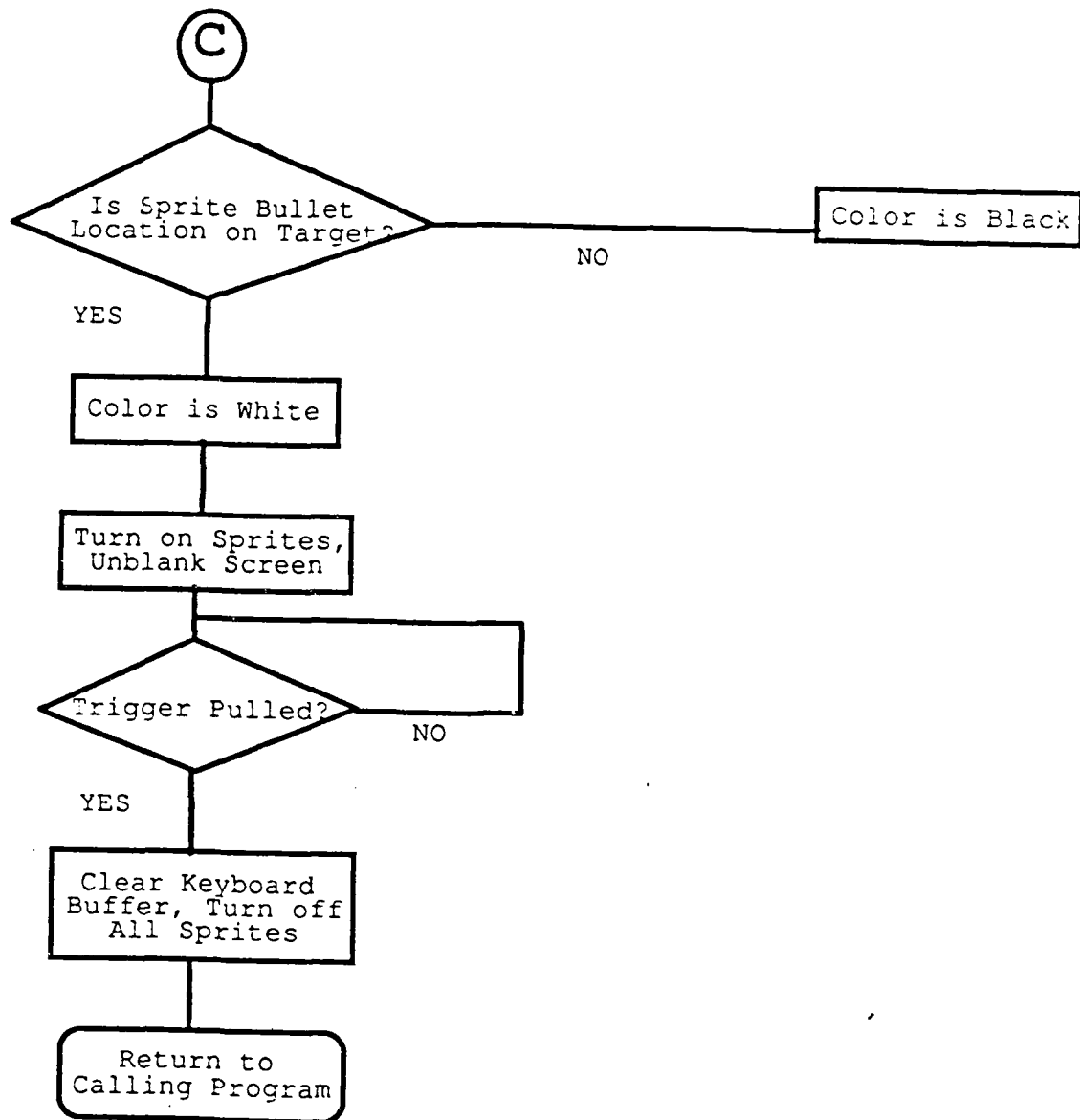
Procedure Zero



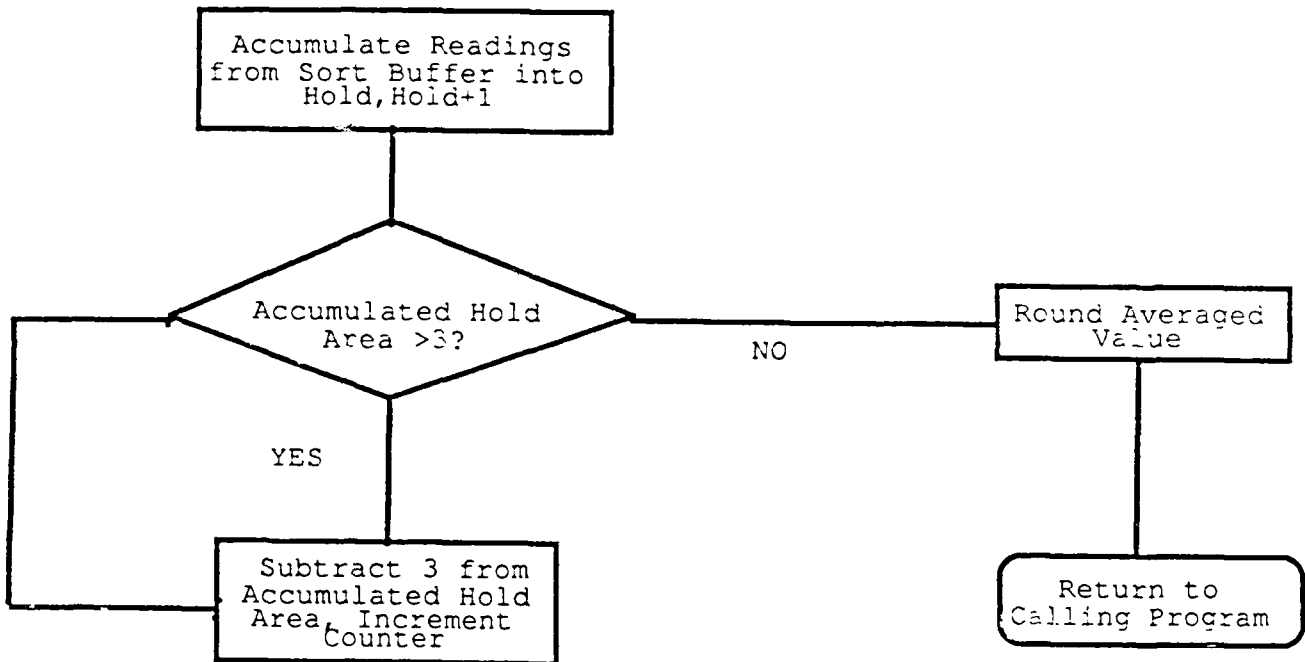
Procedure Zero (continued)



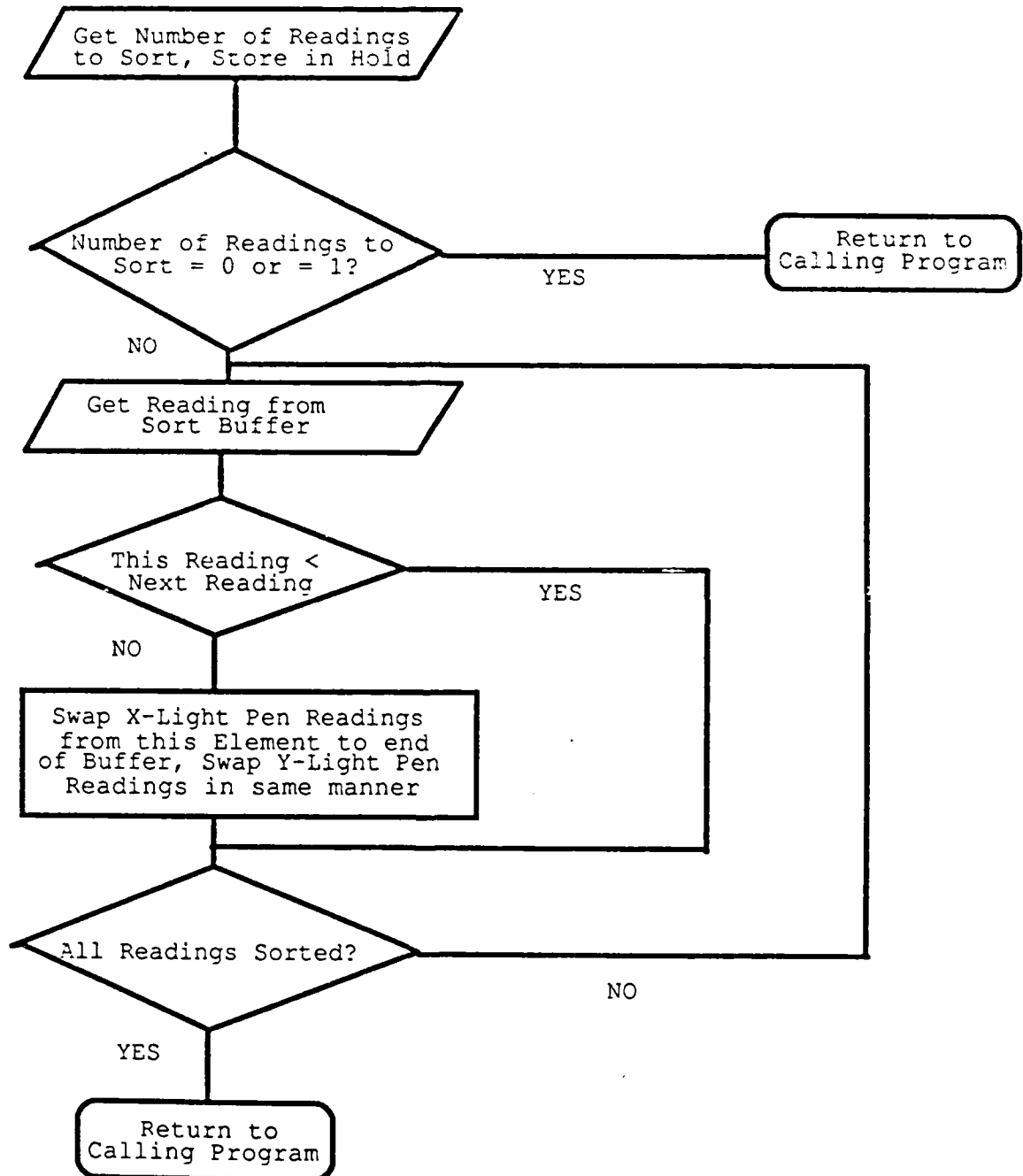
Procedure Zero (continued)



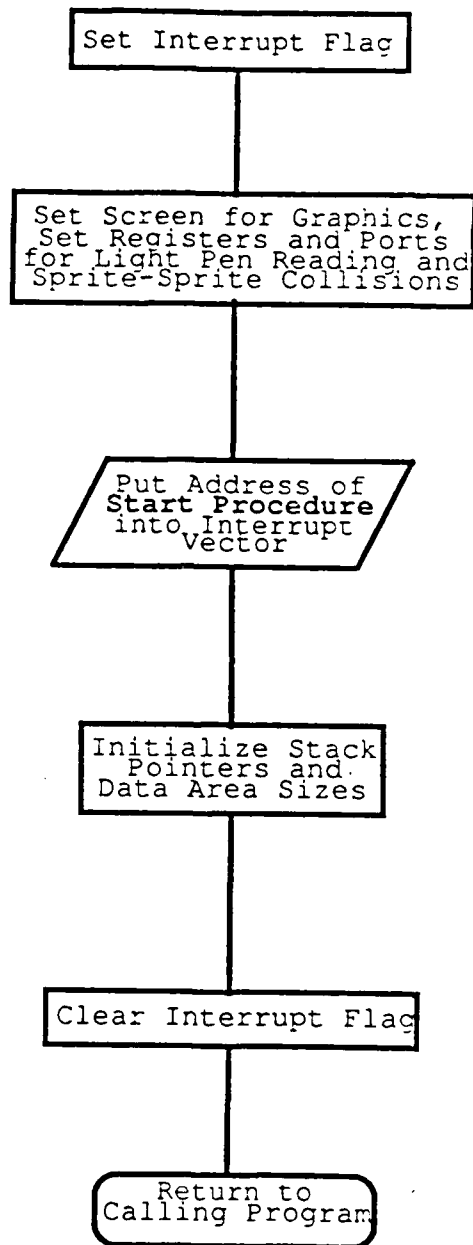
Procedure Avg3



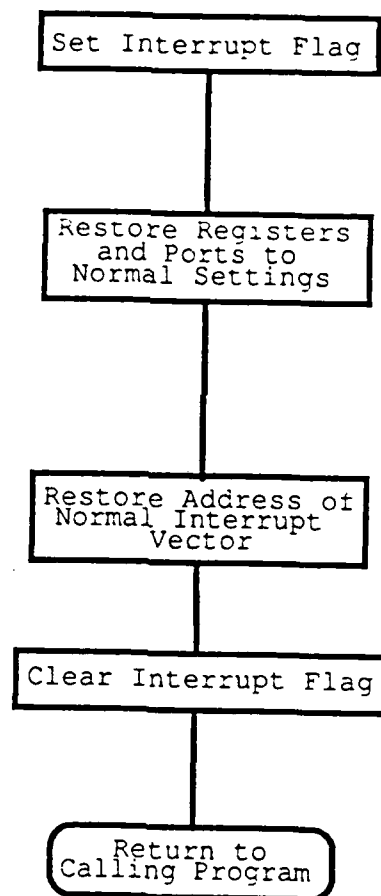
Procedure Sort



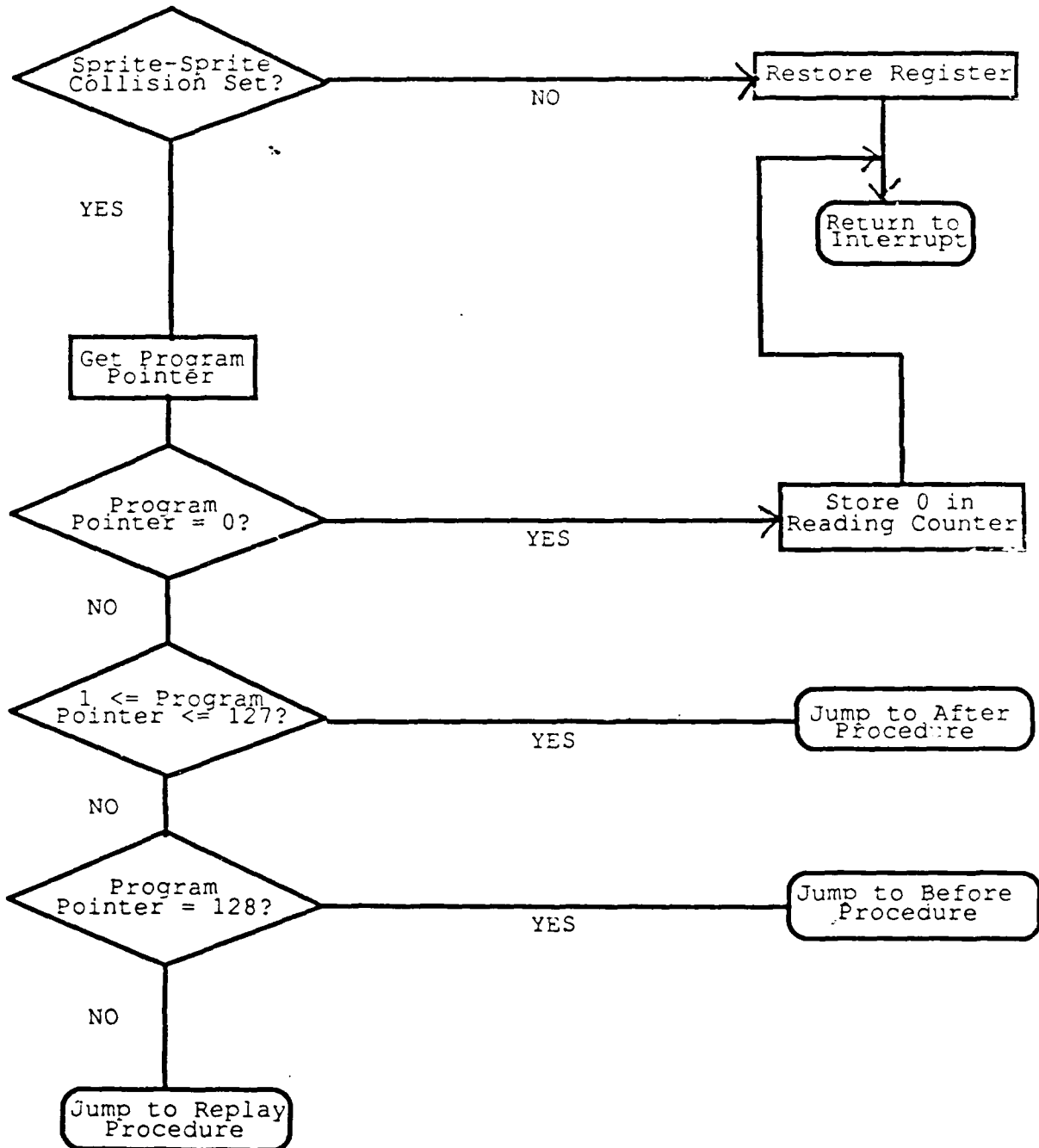
Procedure Enable



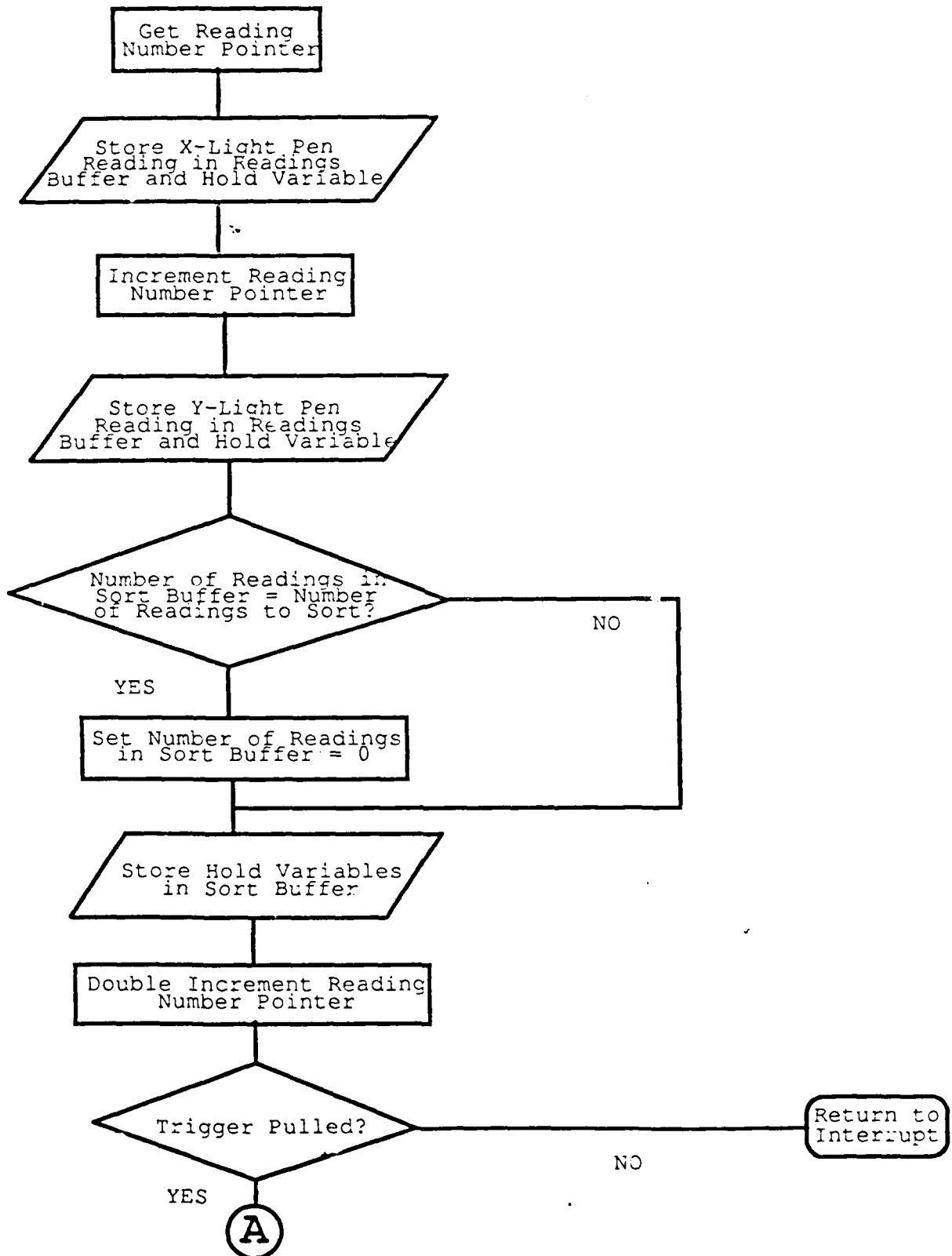
Procedure Disable



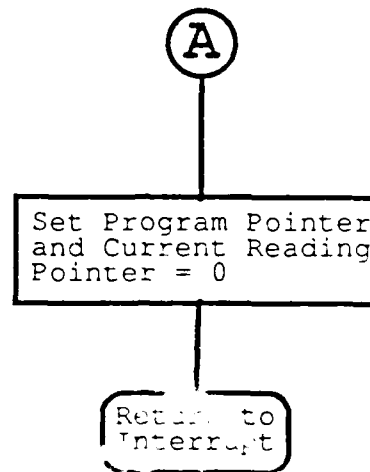
Procedure Start



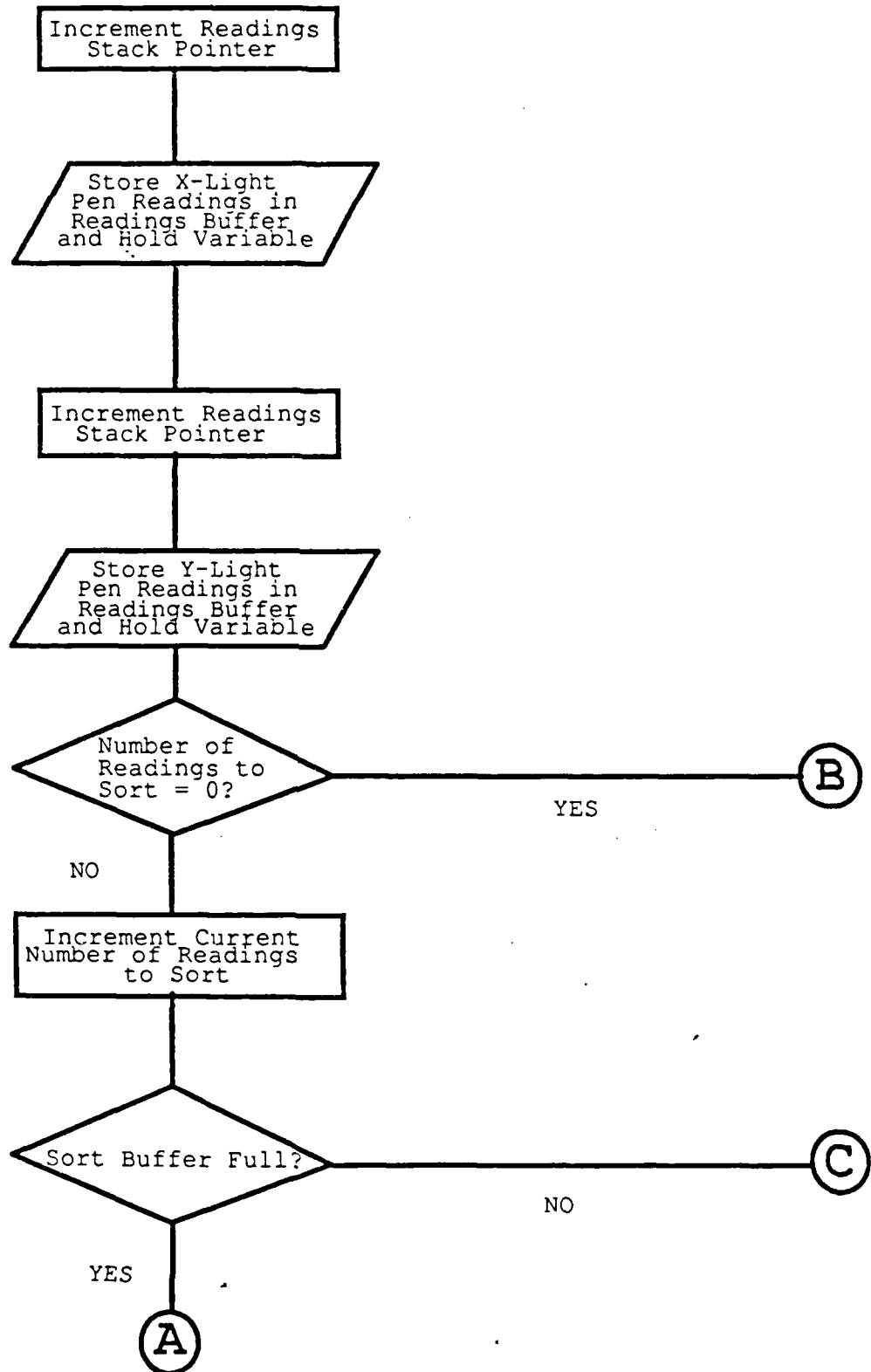
Procedure Before



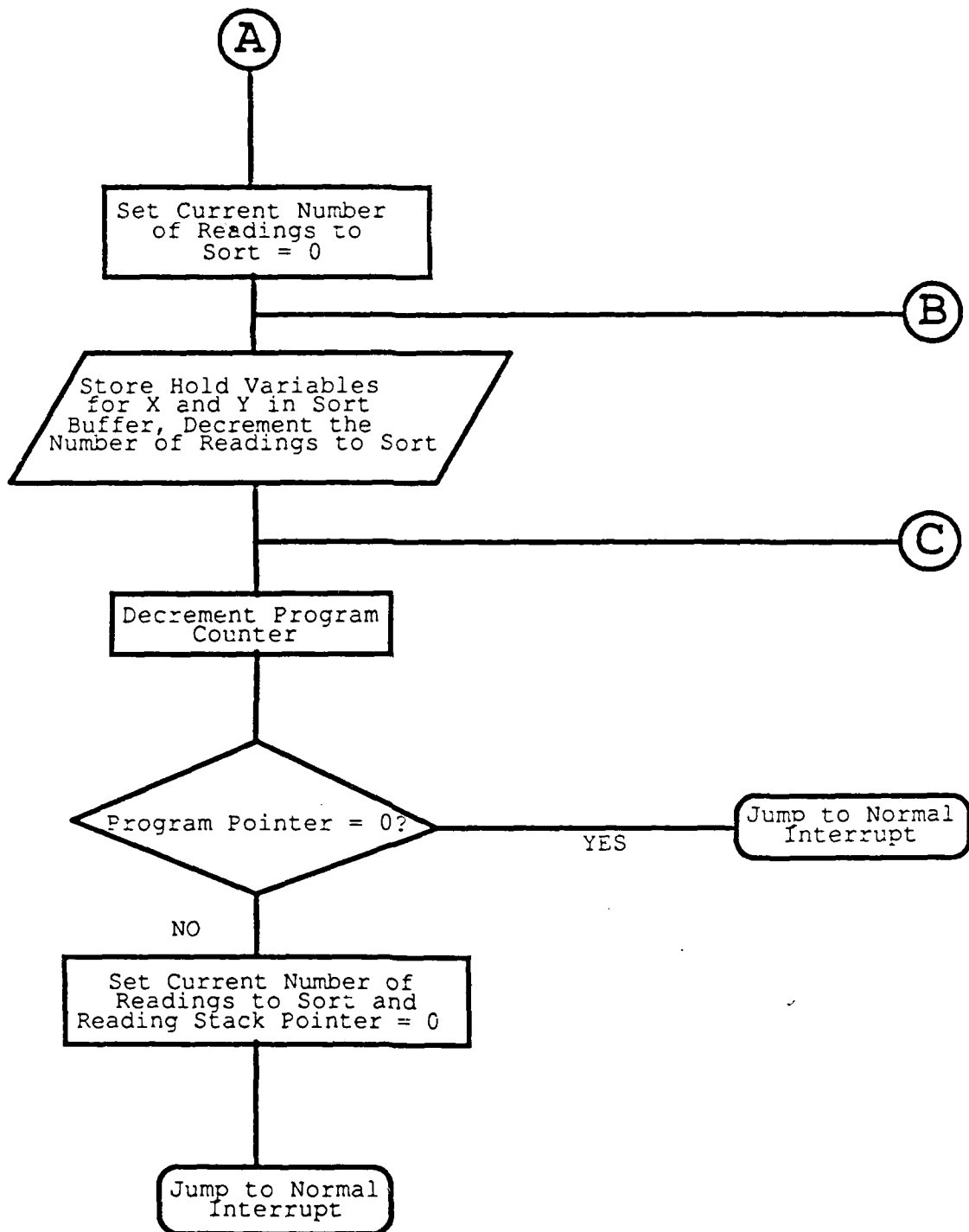
Procedure Before (continued)



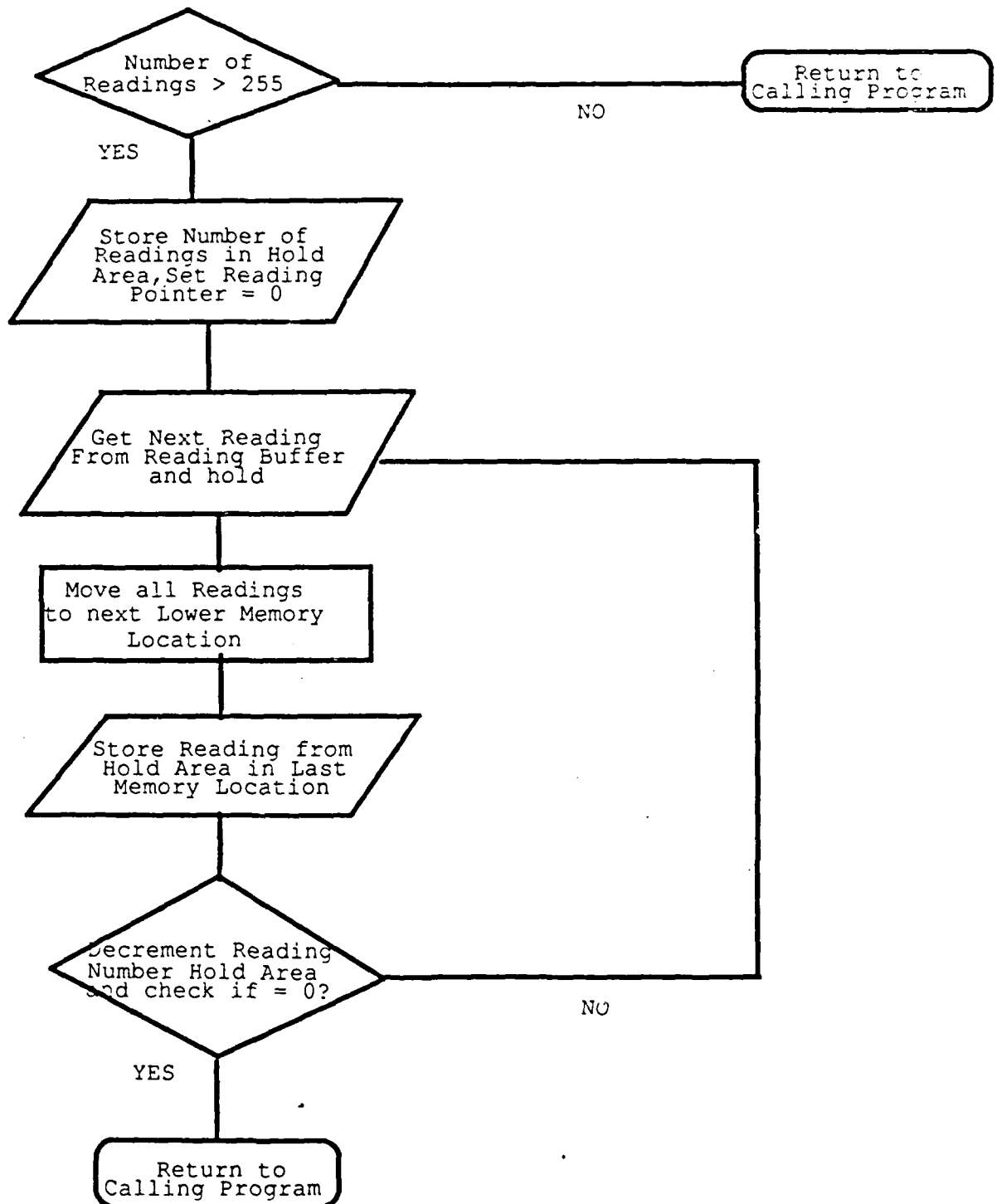
Procedure After



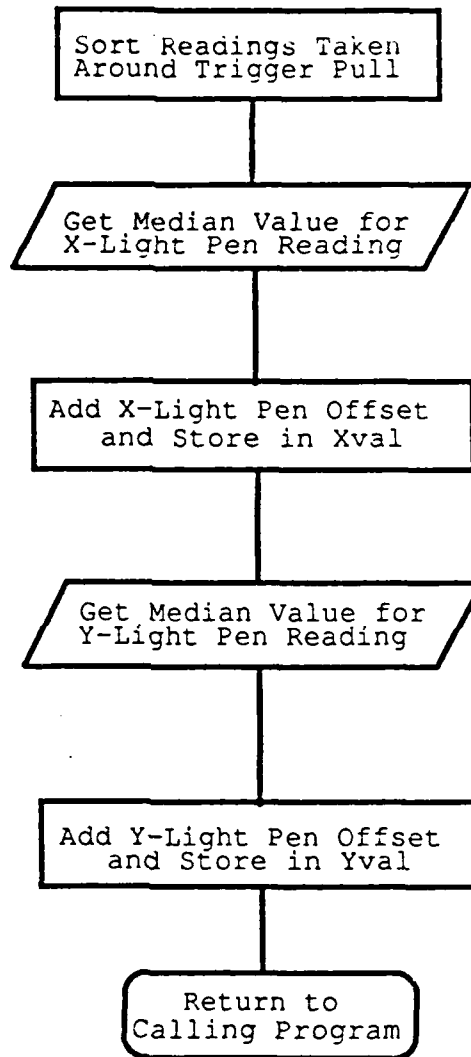
Procedure After (continued)



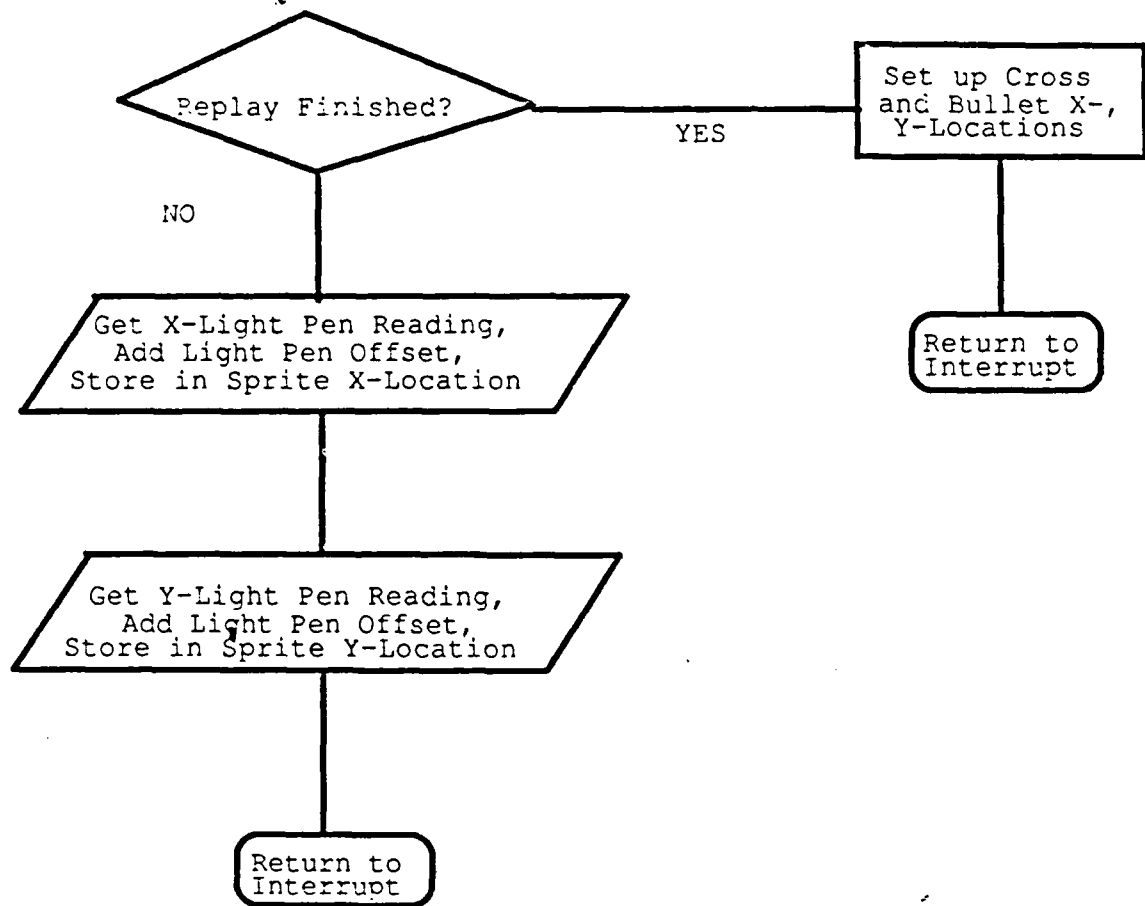
Procedure Rotate



Procedure GetXY



Procedure Replay



APPENDIX B: A LEVEL-BY-LEVEL OUTLINE AND TECHNICAL DOCUMENTATION
OF THE 10-LEVEL BRM CARTRIDGE

MACS BRM CARTRIDGE

- I. Introduction to Supported Position
 - A. No time limit
 - B. Supported position
 - C. Single target presentations
 - D. Targets engaged in order from 50 meters to 300 meters
 - E. 18 targets (3 presentations per range)
 - F. Feedback
 - 1. Diagnostics and replay after each shot
 - 2. Feedback showing three shots on single target after three shots fired
 - 3. Summary screen with average diagnostics scores at end of scenario
 - G. Standards within level (3 more targets presented at the indicated range if standards not met): 2 hits out of 3 targets at all ranges
- II. Introduction to Unsupported Position
 - A. No time limit
 - B. Unsupported position
 - C. Single target presentations
 - D. Targets engaged in order from 50 meters to 300 meters
 - E. 18 targets (3 presentations per range)
 - F. Feedback
 - 1. Diagnostics and replay after each shot
 - 2. Feedback showing three shots on single target after three shots fired.
 - 3. Summary screen with average diagnostics scores at end of scenario
 - G. Standards within level (3 more targets presented at the indicated range if standards not met): 2 hits out of 3 targets at all ranges
- III. Timed Targets in Supported Position
 - A. Time limit approximately 1-1/3 times that of Record fire
 - B. Supported position
 - C. Single target presentations
 - D. 24 targets in random sequence (4 presentations per range)
 - E. Feedback
 - 1. Shot by shot diagnostic feedback for bad shots only (one poor for any score, or a poor or below average for shot location)
 - 2. Summary feedback showing shots at each range on a single target
 - 3. Summary screen with average diagnostics scores at end of scenario
 - F. Standards within level (4 more targets presented at the indicated range if standards not met): 3 hits out of 4 targets at all ranges
- IV. Timed Targets in Unsupported Position
 - A. Time limit approximately 1-1/3 times that of Record fire
 - B. Unsupported position
 - C. Single target presentations
 - D. 24 targets in random sequence (4 presentations per range)
 - E. Feedback
 - 1. Shot by shot diagnostic feedback for bad shots only (one poor for any score, or a poor or below average for shot location)
 - 2. Summary feedback showing shots at each range on a single target
 - 3. Summary screen with average diagnostics scores at end of program

- F. Standards within level (4 more targets presented at the indicated range if standards not met)
 - 1. Three out of four hits at 50 m, 100 m, 150 m, 200 m
 - 2. Two out of four hits at 250 m, 300 m
- V. Practice Record Fire I (Hits and misses shown)
 - A. Time limit same as Record fire
 - B. Supported/unsupported positions
 - C. Single or double presentations
 - D. 40 targets in random sequence
 - E. Feedback
 - 1. Location of bullet strike shown by cross hairs
 - 2. Summary of shot location and hits at end of position and end of course of fire
 - 3. Summary feedback showing shots at each range on a single target at end of each position
 - F. Position repeated if standards not met (15 of 20 hits)
- VI. Practice Record Fire II (Misses shown)
 - A. Time limit same as Record fire
 - B. Supported/unsupported positions
 - C. Single or double presentations
 - D. 40 targets in random target sequence
 - E. Feedback
 - 1. Location of bullet strike shown by cross hairs when firer misses
 - 2. Summary of shot location and hits at end of position and end of course of fire
 - 3. Summary feedback showing shots at each range on a single target at end of each position
 - F. Position repeated if standards not met (15 of 20 hits)
- VII. Record Fire (Targets disappear when hit)
 - A. Time limit same as Record fire
 - B. Supported/unsupported positions
 - C. Single or double presentations
 - D. 40 targets in random sequence
 - E. Feedback
 - 1. Bullet strike not shown (target disappears when hit)
 - 2. Summary of shot location and hits at end of position and end of course of fire
 - 3. Summary feedback showing shots at each range
 - F. Position repeated if standards not met (15 of 20 hits)
- VIII. Rapid Record Fire I (Misses shown)
 - A. Time limit approximately 2/3 times that of Record fire
 - B. Supported/unsupported positions
 - C. Single or double presentations
 - D. 40 targets in random sequence
 - E. Feedback
 - 1. Location of bullet strike shown by cross hairs when firer misses
 - 2. Summary of shot location and hits at end of scenario
 - 3. Summary feedback showing shots at each range
 - F. Position repeated if standards not met (15 of 20 hits)

- IX. Rapid Record Fire II (Targets disappear when hit)
 - A. Time limit approximately 2/3 times that of Record fire
 - B. Supported/unsupported positions
 - C. One or two targets presented at a time
 - D. 40 targets in random sequence
 - E. Feedback
 - 1. Bullet strike not shown (target disappears when hit)
 - 2. Summary of shot location and hits at end of scenario
 - 3. Summary feedback showing shots at each range
 - F. Position repeated if standards not met
- X. Combat Fire (Attack/Retreat)
 - A. Combat fire
 - B. Predetermined attack/retreat scenario
- XI. STANDARDS
 - A. Levels 1-4
 - 1. Regress one level for two Poor scores (Levels 2-4)
 - 2. Stay at same level
 - a. One Poor score
 - b. One Below average score
 - 3. Otherwise pass
 - 4. Steady Position Score, supported
 - a. Excellent: 95-100
 - b. Good: 90-94
 - c. Average: 84-89
 - d. Below average: 79-83
 - e. Poor: 0-78
 - 5. Steady Position Score, unsupported
 - a. Excellent: 92-100
 - b. Good: 87-91
 - c. Average: 81-86
 - d. Below average: 76-80
 - e. Poor: 0-75
 - 6. Trigger Squeeze Score, supported
 - a. Excellent: 96-100
 - b. Good: 92-95
 - c. Average: 87-91
 - d. Below average: 83-86
 - e. Poor: 0-82
 - 7. Trigger Squeeze Score, unsupported
 - a. Excellent: 93-100
 - b. Good: 86-92
 - c. Average: 78-85
 - d. Below average: 71-77
 - e. Poor: 0-70

8. Follow Through Score, supported
 - a. Excellent: 95-100
 - b. Good: 89-94
 - c. Average: 82-88
 - d. Below average: 76-81
 - e. Poor: 0-75
9. Follow Through Score, unsupported
 - a. Excellent: 93-100
 - b. Good: 79-92
 - c. Average: 64-78
 - d. Below average: 50-63
 - e. Poor: 0-49
10. Shot Location Score, supported
 - a. Excellent: 97-100
 - b. Good: 93-96
 - c. Average: 87-92
 - d. Below average: 82-86
 - e. Poor: 0-81
11. Shot Location Score, unsupported
 - a. Excellent: 96-100
 - b. Good: 91-95
 - c. Average: 84-90
 - d. Below average: 78-83
 - e. Poor: 0-77
- B. Levels 5-9
 1. Regress one level for Poor accuracy score
 2. Stay at same level for Below average accuracy score
 3. Otherwise pass
 4. Hits
 - a. Excellent: 39-40
 - b. Good: 35-38
 - c. Average: 30-34
 - d. Below average: 26-29
 - e. Poor: 0-25
 5. Accuracy Score
 - a. Excellent: 97-100
 - b. Good: 95-96
 - c. Average: 92-94
 - d. Below average: 90-91
 - e. Poor: 0-89

XII. FEATURES

- A. External programs may be executed by pressing a key combination at the opening screen
 1. "CA": Calibration program for light pen
 2. "PF": Print data files to screen or printer
- B. Many features can be activated at various points of the program without being prompted
 1. Pressing the break key during target engagement causes a branch to the end of the level
 2. The "m" key can be typed at the opening screen to send the user to the level menu
 3. The break key can be pressed when the level number is being shown to send the user to the level menu

4. Pressing the "@" key instead of squeezing the trigger at the zeroing introductory screen (demonstrating center of mass) causes all zero targets to have the same location on the screen
 5. Pressing the "RZ" key combination at the zeroing feedback screen (diagnostic scores) allows the firer to re-zero
- C. Options in addition to those already visibly present are available at the menu screen
1. "CA": Calibration program for light pen
 2. "PF": Print data files to screen or printer
 3. "SP": Sight picture program
 4. "ZS": Zero and sight change program
 5. "EZ": A toggle to set all level 1 targets to 250 meters or return them to normal
 6. "NU": A toggle to display the diagnostic feedback for the zero procedure as numeric or descriptive

BRM ATTACK/RETREAT SCENARIO (LEVEL 10)

Screen	Target Range	Exposure Time	Running Time Onset/Offset	
1	300	4	1	4
- 5 second delay -				
2	300	7	10	16
	250	6	11	16
	300	5	12	16
- 4 second delay -				
3	250	4	21	24
	200	4	21	24
- 2 second delay -				
4	250	8	27	34
	200	8	27	34
	150	6	29	34
	200	4	31	34
- 5 second delay -				
5	150	4	40	43
	100	3	41	43
- 2 second delay -				
6	150	6	46	51
	100	4	48	51
	50	2	50	51
- 0 second delay -				
7	100	10	51	62
	100	10	51	62
	150	10	51	62
	100	4	57	62
	50	4	57	62
- 0 second delay -				
8	50	10	62	73
	100	10	62	73
	100	10	62	73
	100	10	62	73
	150	2	70	73
- 2 second delay -				
9	100	6	76	81
	150	5	77	81
	150	4	78	81
- 5 second delay -				
10	150	4	87	90
	200	3	88	90
- 2 second delay -				
11	150	8	93	100
	200	8	93	100
	200	8	93	100
	250	6	95	100
- 4 second delay -				
12	250	4	105	108
	250	2	107	108
- 3 second delay -				

Screen	Target Range	Exposure Time	Running Time Onset/Offset	
13	300	7	112	118
	250	7	112	118
	300	6	113	118
- 5 second delay -				
14	300	4	124	127

BRM CARTRIDGE ADDRESSES

	COPY ADDRESS		CHIP ADDRESS		SIZE	TOTAL
Chip 0: Bank 0						
STARTUP	49152	50885	32768	34501	1,734	
PRINT FILES	16384	21168	36141	40925	4,785	
MLPRINTFILES	3400	3433	40926	40959	34	
TOTAL						6,553
Chip 0: Bank 1						
MLCH0BK1	32768	37427	32768	37427	4,660	
UNITS.SCENARIO.3	8192	16191	37466	40383	2,918	
ZERO.SPRITES	2176	2751	40384	40959	576	
TOTAL						8,154
Chip 0: Bank 2						
OPENING.SCENARIO	8192	16191	32768	36932	4,165	
CALIBRATION	16384	17554	39789	40959	1,171	
TOTAL						5,336
Chip 0: Bank 3						
UNITS.3400	3400	7886	32768	37254	4,487	
SIGHT PICTURE	16384	19239	37344	40199	2,856	
ZERO.50090	50090	50810	40239	40959	721	
TOTAL						8,064
Chip 1: Bank 0						
UNITS.BAS (1)	16384	24575	32768	40959	8,192	
TOTAL						8,192
Chip 1: Bank 1						
UNITS.BAS (2)	24576	32767	32768	40959	8,192	
TOTAL						8,192
Chip 1: Bank 2						
UNITS.BAS (3)	32768	34727	32768	34727	1,960	
UNITS.SCENARIO.4	8192	16191	35134	38125	2,992	
ZERO.BAS (1)	16384	19217	38126	40959	2,834	
TOTAL						7,786
Chip 1: Bank 3						
ZERO.BAS (2)	19218	27409	32768	40959	8,192	
TOTAL						8,192
Chip 2: Bank 0						
ZERO.PICTURE.1	8192	16191	32768	40767	8,000	
TOTAL						8,000
Chip 2: Bank 1						
ZERO.PICTURE.2	8192	16191	32768	40767	8,000	
TOTAL						8,000
Chip 2: Bank 2						
UNITS.SCENARIO.1	8192	16191	32768	37444	4,677	
UNITS.SCENARIO.2	8192	16191	37445	40483	3,039	
TOTAL						7,716
Chip 2: Bank 3						
ZERO.3000	3000	7688	32768	37456	4,689	
UNITS.SPRITES	2176	3007	40128	40959	832	
TOTAL						5,521
TOTAL SIZE						89,706

BRM PROGRAM DOCUMENTATION

Basic Hierarchy Chart.

Lines 10-290: Main program driver.

Lines 1000-2460: Subroutines for firing levels.

Lines 1000-1470: The zeroing procedure.

Lines 1480-1670: Firing levels 1 and 2.

Lines 1680-1980: Firing levels 3 and 4.

Lines 1990-2320: Firing levels 5-9.

Lines 2330-2460: Firing level 10.

Lines 2500-5220: Supporting subroutines.

Lines 6000-6120: Data.

Lines 10-290: Main program driver.

Lines 10-60: Initialize variables.

Lines 70-120: Lines 70-290 form the main loop of the program. At this time, the BRM cartridge opening screen is being shown if this is the first time the program is being run. On subsequent runs, the congratulatory screen for successful completion of the scenario is being shown. These lines poll the keyboard for the space bar, the "M" key, or the "CA" or "PF" key combinations which enter the 10-level scenario, go to the menu, or run the calibration or print files programs respectively.

Lines 130-200: Line 130 transfers control to line 210 if variables have been initialized and the option of record keeping has been established. Otherwise, these lines welcome the user to MACS, initialize array variables, and question the user about record keeping.

Lines 210-290: These lines send the firer first to the zeroing routine, and then to the appropriate level of fire. Upon completion of the exercises, the congratulations screen is displayed and control returns to the top of the program at line 70.

Lines 1000-1470: The zeroing procedure.

Lines 1000-1010: If the record keeping option has been specified, the user must now input the firer's identification number.

Lines 1020-1090: These lines show the instructional zeroing screen and check for the trigger to be pulled, or the "@" key to be pressed. If the trigger is pulled, the variable TN is set to 0 and the zero targets are raised with a random horizontal (X) value. If the "@" key is pressed, TN is set to -1 and the zero targets are raised with the same X value (165).

Lines 1100-1120: These lines initialize the variables needed by the interrupt routines and copy the zero target data from its permanent location on the EPROM to its useful place in RAM. This routine is referenced by the BASIC variable DA.

Lines 1130-1140: If the shot number is 0 or 3, i.e., if the user is about to fire the first shot of either firing position, the accumulator for the average diagnostic scores (for the summary) is set to 0 and the firer is instructed to assume the proper position. The high resolution graphic screen must also be displayed at this point.

Lines 1150-1160: The appropriate X coordinate (either 165 or random, as determined by the value of TN) is put into the target data and the address for the target control and light pen reading routine

(referenced by the variable CM) is put into the USR function call registers at 785 and 786.

Line 1170: The target control and light pen reading routine is called. If the routine returns to BASIC as a result of the break key being pressed, control returns to line 1150 and the firer engages another target without advancing the shot counter.

Line 1180: If the shot count is less than 3, the light pen offset x and y values (OX and OY) are incremented.

Lines 1190-1220: The diagnostic scores are computed and the accumulators for the average are adjusted.

Lines 1230-1270: These lines are executed only if the shot count is at 2 (after the third shot has been fired). The light pen offsets can now be determined since the zeroing process has been completed, and the shot locations scores for the first three shots are computed. The three-round shot group and summary diagnostic scores are shown.

Line 1280: If the shot count is less than 6, the program loops back to line 1130.

Line 1290-1310: The shot location scores for shots 3-5 are computed and the three-round shot group and summary diagnostic scores are shown.

Lines 1320-1340: Records of the first six shots are saved to disk if record keeping has been specified, and the program determines a starting level or continues to the extended skill test. If no further testing is required, control is returned to line 210.

Lines 1350-1390: Variables for the extended skill test are set up and the introductory screens displayed.

Lines 1400-1470: Either three or six more shots are fired in this loop for the extended skill test. These lines proceed in similar manner to the regular skill test with the exception of line 1420, which must now consider the possibility of a no fire. Control is returned to line 210 upon completion.

Lines 1480-1670: Firing levels 1 and 2.

Lines 1480-1490: Variable initialization.

Lines 1500-1520: If the current level is 1 and the "EZ" option has been selected, only the data for 250 meter targets is moved. The line which loads all other targets is skipped.

Line 1530: This line moves the data for all targets from EPROM.

Lines 1540-1590: All variables are initialized, and the hires scenario and status line are displayed. A random X coordinate and the no time limit code are recorded in the data for the machine language routines and the trajectory and Y coordinate are obtained from the data for use in future BASIC routines. If the 50 meter target is being engaged, the second sprite is prepared.

Lines 1600-1620: The machine language routine target and light pen control is called in line 1600. POKE 878,0 turns off the cross delay counter so that the cross will remain on the screen and not disappear after one half second. If the break key is pressed during engagement, control is transferred to line 1670 and the subroutine is exited. The hit counter is incremented if the target was hit.

Line 1630: The replay routine is called. If the break key is pressed during the replay, control is transferred to line 1670.

Line 1640: The shot counter is incremented and if it is not the third shot at any target, the target data pointer is restored to the same target and the program loops back to line 1560.

Line 1650: At this point in the routine, three shots have been fired at a target. The shot group is displayed and if the number of hits is 2 or 3, the next target is engaged (beginning at line 1540).

Line 1660: This line indicates the firer did not pass the standards. The number of repetitions counter (RP) is incremented, the "GET READY" message is displayed, the border is changed to red, the number of hits (H) is set to 0, and control is sent to line 1560 for replay of the same target.

Line 1670: All sprates are turned off, summary diagnostic scores are displayed, records are saved to disk if the record keeping option has been set, the next level of fire is determined, and control is returned to line 260.

Lines 1680-1980: Firing levels 3 and 4.

Lines 1680-1730: All variables are initialized and the target data is moved to RAM in random order.

Lines 1740-1780: These lines control the firing for the first round of targets. The work horse of this routine is the subroutine beginning at line 4370, which returns (in the variable Z) 128 if the break key is pressed during the exercise, 64 for a no fire, or 0 to proceed. When all targets have been engaged once, the next set of lines are executed to handle any necessary repetitions.

Line 1790: The summary shot groups for all targets engaged are shown.

Lines 1800-1920: Shots are refired on the targets for which the firer did not qualify. Again, the main routine is the subroutine beginning at line 4370.

Lines 1930-1980: The average diagnostic scores are computed and displayed and the next level of fire is determined. Control is returned to line 260.

Lines 1990-2320: Firing levels 5-9.

Lines 1990-2030: All variables are initialized and the target data for the appropriate level (supported position) is moved to RAM. The main routine at subroutine 3950 is called in line 2030.

Lines 2040-2090: A summary of hit, miss, no fire, accuracy, and penalties is shown. If the break key is pressed during engagement, the subroutine is exited. After shot groups are shown and records saved to disk when requested, the program checks to see if the standards have been met and either returns to line 2010 or continues to the unsupported position.

Lines 2100-2130: All variables are initialized and the target data for the appropriate level (supported position) is moved to RAM. The main routine at subroutine 3950 is called in line 2130.

Lines 2140-2190: After the hit, miss, no fire, accuracy, and penalty summary screen is shown, the shot groups for all targets engaged are shown and records for the unsupported position are saved to disk if requested. If standards have not been met, control returns to line 2110.

Lines 2200-2320: The hit, miss, no fire, accuracy, and penalty summary screen is shown for both firing positions and the next level of fire is determined.

Lines 2330-2460: Firing level 10.

Lines 2330-2370: All variables are initialized and the target data for level 10 is moved from EPROM to RAM. The high resolution graphics screen and status line are displayed.

Lines 2380-2460: The machine language routine controlling the target engagement and light pen collection is entered. Due to the unique timing which is utilized in this level, all targets are displayed by this machine language routine, therefore, very little is done in BASIC. The positions are repeated (with shot groups and record storage to disk in between) until standards are met or the break key is pressed. After successful completion, the current level (CL) variable is set to 11 to signify the conclusion of the program and control is returned to line 260.

Lines 2500-2590: These lines perform the calculations for the diagnostic scores. The machine language routine addressed by DV is called to compute the standard deviations for the steady position scores. For steady position, if the number of readings is less than 15, the routine returns an out of range value so that the score to be computed later will be 0. If the number of readings is greater than 14 but less than 33, the routine uses the window from -14..-7. If the number of readings is greater than 32, the routine uses the window from -31..-7. For trigger squeeze, the routine returns an out of range if the number of readings is less than 7; otherwise, it uses the window from -6..-1. For follow through, the routine uses the window from 1..6.

Lines 2600-2620: These lines use the subroutines at 2500 to compute the standard deviations for steady positions scores and converts the results into a score between 0 and 100. The shot location score is also computed here.

Lines 2630-2640: Certain variables are saved into the array H%.

Lines 2650-2660: Variables which were saved in lines 2630-2640 can be restored by calling this routine.

Lines 2670-2740: With the numeric diagnostic scores in SD%, this routine returns the appropriate descriptive diagnostic score. It is most often called at line 2670, but in certain circumstances, may be called at line 2680 with the diagnostic score in Z4 and the subscript for criterion comparison in Z5. If the current level is 0 (zeroing procedure) and the NU variable (a flag for numeric scores) is not equal to 0, both the descriptive and numeric diagnostic scores are displayed simultaneously.

Lines 2750-2820: The ASSUME (proper) POSITION message is displayed. If PS is 0, the position is supported. For a 1 in PS, it is unsupported. This routine is sometimes called at line 2790 to display the <PULL TRIGGER TO CONTINUE> message, at line 2800 to check for trigger pull, or at line 2810 to check for trigger release.

Line 2830: This procedure prints the string in A\$ to the graphics screen by calling the appropriate machine language routine.

Line 2840: The hires graphics screen at location S1 of chip/bank S2 is displayed.

Lines 2850-2880: The average diagnostic scores from B to E are computed.

Lines 2890-2940: Determines the appropriate next level of fire based on skill test performance.

Lines 2950-3020: These lines display the introductory screen to each level. If the trigger is pulled, the corresponding level is entered. If the break key is pressed, control is transferred to the menu screen.

Lines 3030-3460: The menu screen. This routine displays the options available to the user and accepts input for both hidden and revealed options. The 10 level program is exited if the key combinations "CA", "PF", "ZS" or "SP" are pressed for the programs Calibration, Print Files, Zero and Sight Change, or Sight Picture respectively.

Lines 3470-3490: Initialization for the machine language replay routine.

Lines 3500-3750: Display diagnostic scores and replay for levels 1-4.

Lines 3500-3540: Display diagnostic scores.

Lines 3550-3750: Show replay. The replay target is positioned so that its center of mass is at the point (254,152). The sight post which represents the perfect sight picture is adjusted for wind and trajectory. The replay message is displayed and the center of the screen is colored green by the machine language routine referenced by the variable CO. The replay is interrupt driven, and line 3650 waits for the replay to finish at least once before the trigger can be pulled. Lines 3690-3750 control the pause when the "Pull trigger to continue" message is displayed, waiting for either trigger pull, the break key, or the time limit to expire before showing the replay again.

Lines 3760-3880: Display final diagnostic scores for levels 1-4 and determine the next firing level.

Line 3760: If less than two shots have been fired, the summary scores are not displayed.

Lines 3770-3800: Compute the average diagnostic scores.

Lines 3810-3840: Display the final scores.

Lines 3850-3880: Determine the next firing level. If there is more than one poor score and the current level is greater than 1, the firer must regress a level. If there is a poor score or a score which is below average, the firer must repeat the level. Otherwise, the firer attempts the next level.

Lines 3890-3940: A stack beginning at 16325 is used to store target numbers before the machine language routine referenced by the variable RM is called. By randomizing the numbers in the stack, the RM procedure can take the corresponding target from the data stored on the EPROM and place it in RAM. Before calling this subroutine, the variables B and E must be set to the beginning and ending point in the stack. This technique is used to accommodate those circumstances where two or more sets of targets must be randomized. For levels 5-9, the supported targets must be dealt with before the unsupported targets so that they are not all randomized

together. This subroutine randomizes the stack so that the RM procedure can be called.

Lines 3950-4070: Main scenario routine for levels 5-9.

Lines 3950-4030: These lines perform the initialization process which varies for each level. The variable AD considers the different feedback for hit or miss (cross always, cross only for misses, or cross never) and whether or not the records should be saved to the disk buffer (remember that only the first attempt is saved).

Lines 4040-4060: The machine language target control routine is called, the whistle is blown if a target is left standing after the time limit has expired, and the procedure waits for the cross to disappear before continuing.

Line 4070: A random delay before the next screen is displayed.

Lines 4080-4180: Display shot groups. The target is positioned so that its center of mass is at (172,150) and the shots are displayed by the machine language routine referenced by the variable GP. The shots are actually a two by two bitmap, so the sprites must be forced to have a lower priority than the background. This reversal of the default is accomplished by putting 255 in the register at 53275.

Lines 4190-4360: Display the summary screen of hits, misses, no fires, accuracy, and penalties for levels 5-9.

Lines 4370-4560: Main scenario routine for levels 3-4.

Lines 4370-4440: All variables are initialized and the high resolution graphic screen with status line is displayed.

Line 4450: The hit counter is incremented if a hit was registered on the target.

Line 4460: If the break key was pressed or a no fire was recorded, the subroutine returns to line 1760.

Lines 4470-4560: The diagnostic scores are displayed and the replay is shown if a bad shot is determined. A bad shot is indicated by a poor score in any diagnostic measure or a below average or poor score for shot location.

Lines 4570-4700: Display diagnostic scores and shot group for the skill test. This routine also checks the keyboard for the "RZ" combination and if found, allows the firer to refire the skill test.

Lines 4710-4800: Display summary screen for level 10.

Lines 4810-5070: Save records to disk.

Lines 4810-4830: This subroutine is called by the main subroutine at lines 4920-5070 to position the record at the record number in variable Z and read the error channel.

Lines 4840-4910: This subroutine is called by the main subroutine at lines 4920-5070 to check for the existence of the data file and either open it or create it. The header record is written to disk.

Lines 4920-5070: These lines represent the main record keeping subroutine. Line 4920 checks to see if the record keeping option has been specified and if not, returns to the calling procedure. The user is prompted to insert a new diskette if more than 300 records are

already stored. After the "Please Wait" prompt is displayed, the diagnostic scores (if appropriate for the current level) are stored in temporary memory so the machine language routine can have access to the scores. The machine language routine referenced by the variable SA is called to record the data to diskette.

Lines 5080-5090: The "GET READY" message is displayed and the border is changed to red to signify more target presentations due to a failure to meet standards.

Lines 5100-5130: These lines display the status line after adding the current wind speed and direction.

Lines 5140-5210: This subroutine prompts the user for input at the menu screen. The menu is displayed on the high resolution graphic screen, necessitating a more complex means of obtaining the input. Only two characters or numbers are accepted.

Line 5220: The record keeping buffer is initially set for no fires.

Lines 6000-6120: Data.

APPENDIX C: A LEVEL-BY-LEVEL OUTLINE OF THE MACS 8-LEVEL ARM CARTRIDGE

MACS ARM CARTRIDGE

- i. Three shot zero with option to skip to Level 1
- ii. Demonstration of lead
 - A. Demonstration of what happens when no lead is used
 - B. Demonstration of what happens when proper lead is applied
 - C. Demonstration of single lead sight rule
 - D. Examples of when single lead rule does not work
- iii. Demonstration of track and trap
 - I. Introduction to Moving Target Engagement
 - A. Moving targets at 60 meters at actual speeds of 2 mi/hr, 4 mi/hr, and 8 mi/hr
 - B. Single target presentations
 - C. Three targets travel from left to right at each speed, then right to left for a total of 18 targets
 - D. Pressing CTRL key advances firer to next target speed
 - E. Feedback
 - 1. Diagnostics and replay after each shot
 - 2. Feedback showing three shots on single target after three shots fired (at given speed and direction)
 - F. Standards within level - 2 hits out of 3 targets (3 more targets presented if standards not met)
 - II. Introduction to Moving Target Engagement
 - A. Moving targets at 75 meters at actual speeds of 2 mi/hr, 4 mi/hr, and 8 mi/hr
 - B. Single target presentations
 - C. Three targets travel from left to right at each speed, then right to left for a total of 18 targets
 - D. Pressing CTRL key advances firer to next target speed
 - E. Feedback
 - 1. Diagnostics and replay after each shot
 - 2. Feedback showing three shots on single target after three shots fired (at given speed and direction)
 - F. Standards within level - 2 hits out of 3 targets (3 more targets presented if standards not met)
 - III. Introduction to Moving Target Engagement
 - A. Moving targets at 125 meters at actual speeds of 2 mi/hr, 4 mi/hr, and 8 mi/hr
 - B. Single target presentations
 - C. Three targets travel from left to right at each speed, then right to left for a total of 18 targets
 - D. Pressing CTRL key advances firer to next target speed
 - E. Feedback
 - 1. Diagnostics and replay after each shot
 - 2. Feedback showing three shots on single target after three shots fired (at given speed and direction)
 - F. Standards within level - 2 hits out of 3 targets (3 more targets presented if standards not met)

- IV. Introduction to Moving Target Engagement
 - A. Moving targets at 185 meters at actual speeds of 2 mi/hr, 4 mi/hr, and 8 mi/hr
 - B. Single target presentations
 - C. Three targets travel from left to right at each speed, then right to left for a total of 18 targets
 - D. Pressing CTRL key advances firer to next target speed
 - E. Feedback
 - 1. Diagnostics and replay after each shot
 - 2. Feedback showing three shots on single target after three shots fired (at given speed and direction)
 - F. Standards within level - 2 hits out of 3 targets (3 more targets presented if standards not met)
- V. Practice Fire I
 - A. Stationary targets from 50 meters to 300 meters
 - B. Moving targets from 60 meters to 185 meters
 - C. Single targets presented randomly
 - D. Stationary targets presented twice (12 total) and moving targets presented at each speed, in each direction (24 total)
 - E. Time limit for stationary targets approximately 2/3 that of record fire
 - F. Feedback
 - 1. Shot by shot diagnostic feedback for bad shots only (one poor for any score, or a poor or below average for shot location)
 - 2. Hit, miss and no fire summary at end of scenario
 - G. Standards within level - 2 hits out of 3 targets on moving targets, 2 out of 2 hits on stationary targets up through 250 meters, 1 out of 2 hits at 300 meter stationary target
- VI. Practice Fire II
 - A. Thirty targets: twenty moving and ten stationary
 - B. Multiple target presentations
 - C. Forty rounds allowed (30 targets/40 rounds is default, hidden option for number of rounds desired)
 - D. Feedback
 - 1. Shot location feedback only
 - 2. Hit, miss and no fire summary at end of scenario
 - E. Standards within level (15 hits out of 20 targets for movers, 8 hits out of 10 targets for stationary)

VII. Combat Fire I (Attack/Retreat)

- A. Thirty targets: twenty moving and ten stationary
- B. Multiple target presentations
- C. Forty rounds allowed (30 targets/40 rounds is default, hidden option for number of rounds desired)
- D. Feedback
 - 1. Shot location feedback only
 - 2. Hit, miss and no fire summary at end of scenario
- E. Standards within level (15 hits out of 20 targets for movers, 8 hits out of 10 targets for stationary)

VIII. Combat Fire II (Counterattack/Retreat)

- A. Thirty targets: twenty moving and ten stationary
- B. Multiple target presentations
- C. Forty rounds allowed (30 targets/40 rounds is default, hidden option for number of rounds desired)
- D. Feedback
 - 1. Shot location feedback only
 - 2. Hit, miss and no fire summary at end of scenario
- E. Standards within level (15 hits out of 20 targets for movers, 8 hits out of 10 targets for stationary)

ARM ATTACK/RETREAT SCENARIOS (LEVELS 6-8)

Level 6: Practice Fire II Multiple Targets

Screen	Target Range	Target Type	Speed	Direction	Exposure Time	Running Time Onset/Offset	
1	300	S			7	1	7
	300	S			5	3	7
- 2 second delay -							
2	250	S			5	10	14
	185	M	8	L-R	5	10	14
- 3 second delay -							
3	200	S			3	18	20
	185	M	2	L-R	4	20	23
	125	M	4	R-L	6	23	28
- 8 second delay -							
4	250	S			4	37	40
	150	S			4	37	40
- 6 second delay -							
5	185	M	4	L-R	11	47	57
	75	M	4	R-L	4	50	53
	125	M	2	L-R	8	53	60
	75	M	4	L-R	4	55	58
- 10 second delay -							
6	75	M	8	R-L	2	69	70
	125	M	4	L-R	7	71	77
	100	S			3	76	78
	60	M	4	L-R	4	79	82
	75	M	2	L-R	6	79	84
- 1 second delay -							
7	100	S			4	86	89
	75	M	2	R-L	6	86	91
	60	M	4	L-R	4	92	95
	75	M	2	L-R	4	96	99
	100	S			7	100	106
	125	M	4	R-L	6	100	105
- 0 second delay -							
8	50	S			3	106	108
	60	M	2	L-R	3	109	111
	75	M	4	R-L	4	112	115
- 3 second delay -							
9	60	M	4	L-R	3	119	121
	125	M	8	R-L	3	122	124
	185	M	4	L-R	6	125	130

Level 7: Combat Fire I (Attack/Retreat)

Screen	Target Range	Target Type	Speed	Direction	Exposure Time	Running Time Onset/Offset	
1	185	M	8	L-R	5	8	12
- 3 second delay -							
2	300	S			4	16	19
	250	S			3	16	18
	185	M	4	R-L	6	16	21
- 3 second delay -							
3	200	S			4	25	28
	200	S			4	25	28
	185	M	2	R-L	4	27	30
	300	S			4	31	34
- 8 second delay -							
4	150	S			4	43	46
	100	S			4	45	48
	125	M	8	L-R	3	40	51
	125	M	2	L-R	6	49	54
	185	M	4	R-L	4	55	58
	125	M	8	L-R	4	59	62
- 5 second delay -							
5	75	M	4	R-L	4	68	71
	60	M	4	L-R	4	72	75
	75	M	4	R-L	4	76	79
	75	M	4	L-R	4	80	83
	60	M	4	R-L	4	80	83
- 2 second delay -							
6	100	S			4	86	89
	50	S			4	86	89
	75	M	8	L-R	2	90	91
	125	M	8	R-L	4	92	95
	75	M	8	L-R	2	96	97
	75	M	4	L-R	4	96	99
- 2 second delay -							
7	60	M	8	L-R	2	102	103
	75	M	2	R-L	3	104	106
	125	M	4	L-R	4	107	110
	150	S			3	111	113
	185	M	8	R-L	5	114	118

Level 8: Combat Fire II (Counterattack/Retreat)

Screen	Target Range	Target Type	Speed	Direction	Exposure Time	Running Time Onset/Offset	
1	200	S			3	1	4
	185	M	0,8	R-L	2,5	5	11
	150	S			3	5	7
	125	M	0,8	R-L	2,3	12	16
	100	S			2	12	13
	125	M	4	R-L	5	17	21
- 1 second delay -							
2	75	M	8	R-L	2	23	24
	75	M	4	R-L	4	23	26
	125	M	0,8	L-R	1,3	27	30
	60	M	4	R-L	3	31	33
	50	S			3	33	35
- 3 second delay -							
3	75	M	8	L-R	2	39	40
	75	M	4	L-R	4	39	42
	125	M	0,8	R-L	1,3	43	46
	100	S			5	47	51
	60	M	0,8	L-R	1,1	47	48
	100	S			5	47	51
- 5 second delay -							
4	60	M	8	R-L	2	57	58
	75	M	4	L-R	4	58	61
	125	M	8	R-L	3	62	64
	75	M	4	L-R	4	65	68
	125	M	8	R-L	3	69	71
	150	S			3	71	73
- 3 second delay -							
5	125	M	2	L-R	3	77	79
	125	M	4	R-L	3	78	80
	200	S			2	81	82
	185	M	2,8	R-L	2,3	84	88
	250	S			2	89	90
	185	M	8,2	L-R	2,3	91	95
	300	S			3	96	98

ARM CARTRIDGE ADDRESSES

	COPY ADDRESS		CHIP ADDRESS		SIZE	TOTAL
Chip 0: Bank 0						
STARTUP	49152	50920	32768	34536	1,769	
ARM.SCENARIO.3	8192	16191	38042	40959	2,918	
TOTAL						4,687
Chip 0: Bank 1						
MLCH0BK1	32768	40486	32768	40488	7,721	
TOTAL						7,721
Chip 0: Bank 2						
OPENING.SCENARIO	32768	36932	32768	36932	4,165	
DEMO.3400	3400	7206	37153	40959	3,807	
TOTAL						7,972
Chip 0: Bank 3						
PRINT FILES	16384	21645	32768	38029	5,262	
MLPRINTFILES	3400	3433	40926	40959	34	
TOTAL						5,296
Chip 1: Bank 0						
ARM.BAS (1)	16384	24575	32768	40959	8,192	
TOTAL						8,192
Chip 1: Bank 1						
ARM.BAS (2)	24576	32767	32768	40959	8,192	
TOTAL						8,192
Chip 1: Bank 2						
ARM.BAS (3)	32768	33480	32768	33480	713	
ARM.3400	3400	8058	36301	40959	4,659	
TOTAL						5,372
Chip 1: Bank 3						
DEMO.BAS	16384	23289	32768	39673	6,906	
CALIBRATION	16384	17554	39789	40959	1,171	
TOTAL						8,077
Chip 2: Bank 0						
DEMO.SCENARIO	40960	48554	32768	40362	7,595	
DEMO.SPRITES	2176	2751	40384	40959	576	
TOTAL						8,171
Chip 2: Bank 1						
ARM.SCENARIO.1	8192	16191	32768	37444	4,677	
ARM.SPRITES	2176	3135	37445	38404	960	
DEMO.50000	50000	51106	39853	40959	1,107	
TOTAL						6,744
Chip 2: Bank 2						
ARM.SCENARIO.2	8192	16191	32768	35806	3,039	
TOTAL						3,039
Chip 2: Bank 3						
Unused						
TOTAL SIZE						73,463

APPENDIX D: WORK PERFORMED ON THE CARTRIDGE FOR UNIT TRAINING

Point Values for Hits*

50 m - 10 points	250 m - 40 points
60 m - 10 points	300 m - 50 points
75 m - 10 points	400 m - 100 points
100 m - 20 points	500 m - 150 points
125 m - 20 points	600 m - 200 points
150 m - 20 points	700 m - 250 points
185 m - 20 points	800 m - 300 points
200 m - 30 points	

Additional Factors

- *2 for an unusually difficult or unrealistic exposure
- *1.5 rapid record fire exposure times ($\geq 2/3$)
- *1.5 exposure times less than rapid record fire
- *x where x is number of targets presented in multiple exposure screen
- *1/x where x is percentage of target mass exposed in a partially covered/concealed target
- *2 for ranges in any wind condition where ideal aim point is off the target, but front sight still on or touching target
- *3 for ranges in any wind condition where ideal aim point requires entire front sight post to be off the target
- *2 for each center of mass hit
- *1.5 5 mph wind
- *2 10 mph wind
- *3 20 mph wind
- *1.5 night fire or artificial illumination

*All of the scoring mechanisms have been incorporated although some of the actual features have not as yet been implemented.